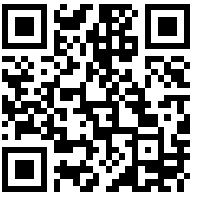

ANOPHELES GAMBIAE IN BRAZIL

1930 to 1940

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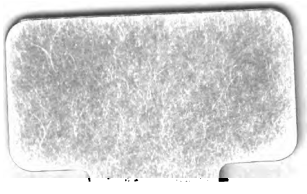
Ann Arbor, Michigan 48109



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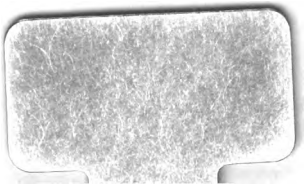

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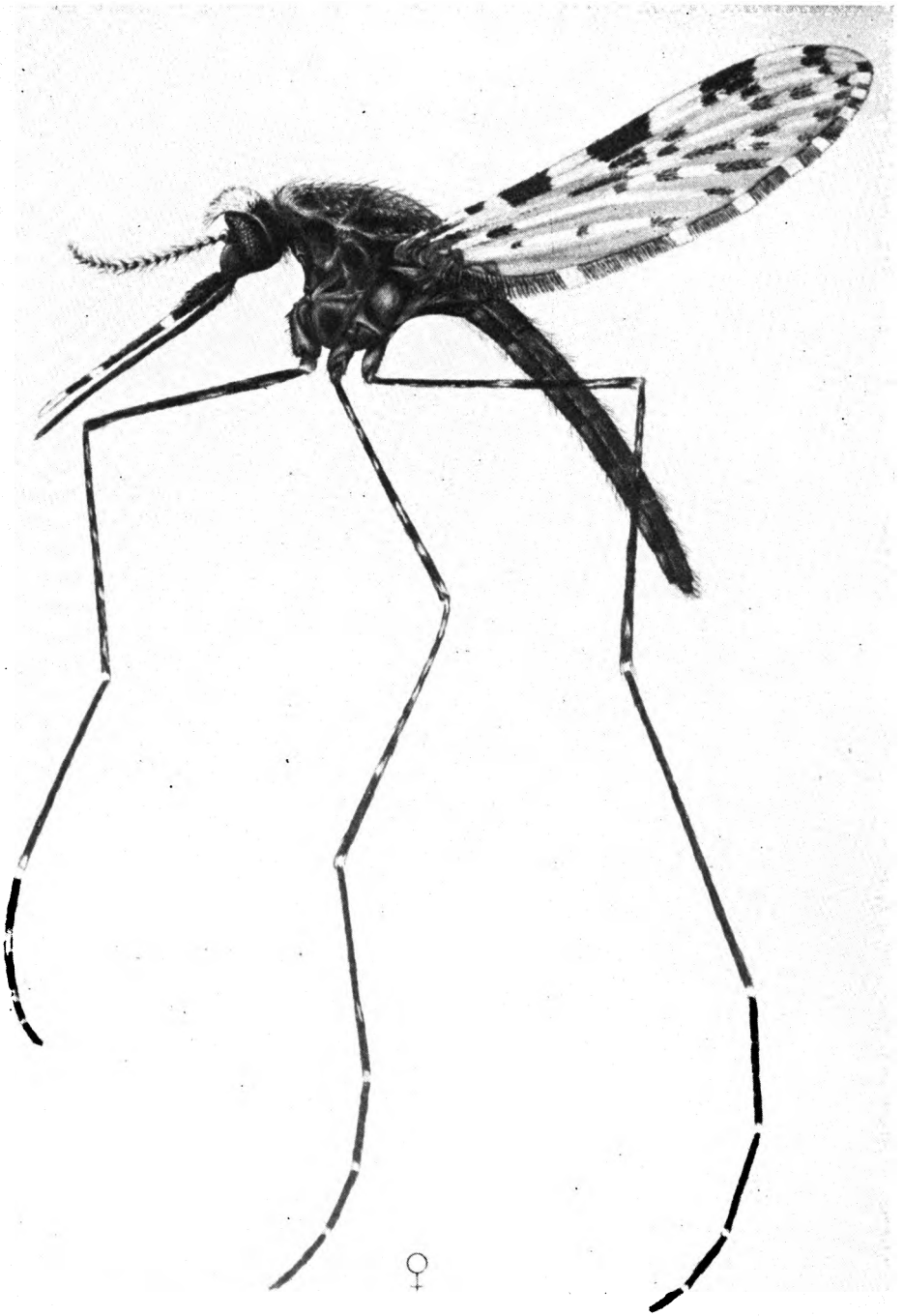
1930 to 1940



♀

= ANOPHELES GAMBIAE =

ANOPHELES GAMBIAE IN BRAZIL

1930 to 1940

By

FRED L. SOPER

and

D. BRUCE WILSON

THE ROCKEFELLER FOUNDATION

New York City

1943

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ACKNOWLEDGMENTS

A special note of recognition is due to those persons who were responsible for approving the program and budgets of the Malaria Service of the Northeast for the years 1939 and 1940, at a time when there was very little concrete evidence of the possibility of species eradication. It is a pleasure to place at the head of the list the names of Dr. Getulio Vargas, the President of Brazil, and of Dr. Gustavo Capanema, the Minister of Education and Health, both of whom took a personal interest in the Malaria Service of the Northeast and never failed to meet its demands, which must at times have seemed excessive.

To Mr. Raymond B. Fosdick, President of The Rockefeller Foundation, to Dr. W. A. Sawyer, Director of the International Health Division, as well as to the individual members of the Board of Scientific Directors of the International Health Division,[1] sitting in New York, special credit must be given for their willingness to assume the responsibility for granting large sums of money to what at times, and from a distance, must have seemed an impossible project.

Mention has already been made of the action of Dr. Barros Barreto who, as Director of the National Department of Health, was responsible for recommending to his government the organization of a cooperative project under the auspices of the International Health Division. Special mention must be made of the kindly dignified interest and collaboration of Dr. Samuel Libanio who, during the most critical stages of the campaign against the *Anopheles gambiae* mosquito, namely from June 1939 to April 1941, occupied the directorship of the National Department of Health.

[1] The Board of Scientific Directors which approved the budget for 1940 consisted of the following members: Wilbur A. Sawyer, M.D.; Ernest W. Goodpasture, M.D.; Stanhope Bayne-Jones, M.D.; Harry S. Mustard, M.D.; Thomas Parran, M.D.; Lowell J. Reed; Felix J. Underwood, M.D.

Brief reference has been made during the present report to the work of Dr. Evandro Chagas and the group of colleagues working under his direction. In the untimely death of Dr. Chagas, in November 1940, Brazilian epidemiologists lost a leader and we of the Malaria Service of the Northeast, a valued friend and collaborator.

It is a pleasure to record the collaboration of the Oswaldo Cruz Institute of Rio de Janeiro and of the Institute of Hygiene of São Paulo, both of which graciously loaned staff members for the work of the Malaria Service. During several months of 1939, Drs. Oliveira Castro and Gilberto Freitas of the Oswaldo Cruz Institute were members of the laboratory, and Dr. Paulo Antunes, of the Institute of Hygiene, took an active and important part in the administration of the field work from April 1939 to July 1941.

An entirely individual and personal expression of gratitude is due Dr. M. A. Barber, who in the course of an extended trip through Latin America in 1939, was pressed into service as a volunteer worker, without salary, during the months of May, June, and July. Dr. Barber made valuable contributions to the success of the Service through the demonstration of the simpler methods of Paris green application and of many refinements of laboratory techniques for the study of both mosquitoes and parasites. Dr. Barber's field work, under a tropical sun, in investigating the relationship of gambiae to malaria in the frontier zones (Barber 1940), put to shame the physical resistance of much younger men. To Dr. Barber the Malaria Service of the Northeast owes the coinage of the most poignant criticism of its early months —viz., that it was not getting the desired results because, as a "shade-loving Service," it failed to contact the "sun-loving larvae" of gambiae.

Mr. R. C. Shannon, who made the original observation of gambiae on the American continent in 1930 and surveyed Northeast Brazil for extensions of its range at the end of the dry season

in the same year (Shannon 1932) and with Gastão Cesar de Andrade made the 1938 (Shannon and Andrade, 1940) dry season survey, returned to the infested area in August 1939 and once more gave the Malaria Service his valuable collaboration. His knowledge of gambiae's dry season biology was based on prolonged, careful observations in the field projected against his unexcelled background of observation of the biology of other anopheles in various parts of the world.

The authors take great pleasure in putting on record the names of the colleagues who took part in the work of the Malaria Service of the Northeast and only regret that it is not possible to put on record the individual efforts of thousands of others who risked malaria infection and who worked under very difficult conditions to carry out the measures on which the success of the campaign against gambiae depended. Among these thousands, as among the doctors of the Service, were many who had proven their dependability by long years of loyal work in the Yellow Fever Service campaign against *Aedes aegypti*.

Of the names which are listed on the following page, it is impossible to pass over without particular mention those of Drs. Mario Franca and Oswaldo Silva, who as assistants shouldered extra heavy responsibilities.

A special place must be given to the name of Dr. Manoel Ferreira, the Director of the Antimalaria Service, who recommended that it be discontinued to make way for the Malaria Service of the Northeast. Dr. Ferreira continued as assistant in the new Service for the first fifteen months of its existence and only after organizing the Central Laboratory and seeing the Service well on its way to success did he abandon it in favor of urgent personal interests.

The two nonmedical assistants, Snrs. Juarez Corrêa Lemos and Deusdedite Campos Alves merit special mention: without them the task of the medical staff would have been a great deal more arduous.

MEDICAL STAFF OF THE MALARIA SERVICE OF THE NORTHEAST

NAME	PERIOD OF SERVICE	
Assistant Directors		
Manoel José Ferreira, M.D.	January 1, 1939	April 5, 1940
Mario Franca, M.D.	January 14, 1939	June 30, 1942
Paulo Cesar de Azevedo Antunes, M.D.	April 23, 1939	August 27, 1941
Oswaldo José da Silva, M.D.	January 27, 1939	June 30, 1942
Positions Held June 30, 1940		
Laboratory		
Ottis R. Causey, M.D.	August 4, 1939	June 30, 1942
Gustavo M. de Oliveira Castro, M.D.	April 1, 1939	September 30, 1939
Henrique Maia Penido, M.D.	December 27, 1939	October 3, 1941
Gladstone de Mello Deane, M.D.	June 14, 1939	October 16, 1939
Leonidas de Mello Deane, M.D.	June 14, 1939	June 30, 1942
Maria Paumgartten Deane, M.D.	June 16, 1939	June 30, 1942
Antonio Conserva Feitoza, M.D.	April 28, 1939	April 7, 1940
Epidemiology Section		
Richard G. Hahn, M.D.	September 8, 1939	December 4, 1940
Carlos Eugenio Porto, M.D.	January 20, 1940	July 15, 1941
Cartographic Section		
C. G. Inman	April 1, 1939	June 30, 1942
Division Directors		
Ceará		
Gastão Cesar de Andrade, M.D.	January 18, 1939	June 21, 1942
Frederico Acquer, M.D.	June 14, 1939	July 31, 1941
Octavio Pinto Severo, M.D.	September 30, 1939	February 9, 1941
Jefferson Carlos de Souza, M.D.	June 16, 1939	November 1, 1941
Miguel Scaff, M.D.	February 10, 1939	September 3, 1939
Antonio da Silva Maltez Filho, M.D.	June 10, 1939	August 22, 1940
Luiz Ferreira Tavares Lessa, M.D.	January 18, 1939	August 31, 1939
Rio Grande do Norte		
Eleyson Cardoso, M.D.	January 22, 1939	November 19, 1940
Fernando Machado Bustamante, M.D.	January 1, 1939	June 8, 1942
Abelardo Buarque Lima, M.D.	April 6, 1939	November 11, 1940
Assistants		
Plinio Teófilo de Aguiar, M.D.	January 10, 1939	June 21, 1942
Nisomar Pinheiro de Azevedo, M.D.	November 1, 1939	June 9, 1942
Arnobio Calheiros Bomfin, M.D.	June 22, 1939	June 21, 1942
Garibaldi Bezerra de Faria, M.D.	December 11, 1939	June 21, 1942
Eliezer Pará-Assú de Serra Freire, M.D.	September 20, 1939	June 21, 1942
Lauro Melloni, M.D.	May 24, 1940	May 31, 1942
Durval Bustorff Pinto, M.D.	February 11, 1939	June 21, 1942
Darcy da Rosa, M.D.	May 28, 1940	May 31, 1942

NAME	PERIOD OF SERVICE	
Mario Machado Sampaio, M.D.	December 13, 1939	June 30, 1942
Orlando José da Silva, M.D.	June 24, 1939	May 21, 1942
Vival Silva, M.D.	April 22, 1940	June 30, 1942
Antonio Mello de Siqueira, M.D.	November 3, 1939	June 6, 1942
Ruy Soares, M.D.	September 25, 1939	June 21, 1942
Vicente Zambrano, M.D.	October 1, 1940	June 30, 1942
José Pedro Bezerra, M.D.	January 1, 1939	September 5, 1940
Carlos Vinha, M.D.	January 1, 1939	February 29, 1940
João Damasceno da Costa, M.D.	April 14, 1939	August 31, 1939
Ivo Bugano, M.D.	November 3, 1939	April 10, 1942
Gilberto de Freitas, M.D.	May 1, 1939	November 18, 1939
Oswaldo Novis, M.D.	March 4, 1939	June 23, 1939
Joaquim Gracindo Marques, M.D.	March 23, 1939	December 24, 1939
Irun Sant'Anna, M.D.	July 10, 1939	December 12, 1939
Germano Silval Faria, M.D.	March 9, 1939	December 24, 1939
Marcolino Gomes Candau, M.D.	June 14, 1939	January 4, 1940
Alcides de Albuquerque, M.D.	December 20, 1939	March 20, 1940
Mario Batinga de Araujo Lessa, M.D.	September 29, 1939	February 29, 1940
Nelson Camillo de Almeida, M.D.	November 1, 1939	March 31, 1940
Werther Leite de Castro, M.D.	December 8, 1939	April 3, 1940
Manoel A. F. C. Couto, M.D.	November 1, 1939	June 1, 1940
Seraphim Paulo Werner, M.D.	March 13, 1939	June 5, 1940
Arnaldo Neves, M.D.	December 8, 1939	July 31, 1940
Lourival de Souza Neiva, M.D.	December 12, 1939	August 7, 1940
Luciano Moura Soares, M.D.	March 6, 1940	August 15, 1940
Eduardo de Souza, M.D.	April 3, 1940	September 9, 1940
Gentil Portugal do Brasil, M.D.	December 8, 1939	September 11, 1940
Edmundo Barros Leite, M.D.	December 8, 1939	September 23, 1940
Rubens Bezerra Valente, M.D.	November 1, 1939	October 3, 1940
Decio Guanabarino Freiria, M.D.	September 30, 1939	December 31, 1940
Nelson de Carvalho Teixeira, M.D.	December 5, 1939	January 7, 1941
Antonio Bernabé Martines, M.D.	September 23, 1939	May 31, 1941
Ramon Affonso Anhel, M.D.	December 11, 1939	June 30, 1941
Osorio Tenorio Lima, M.D.	April 15, 1939	August 8, 1941
Carlos Renato Grey, M.D.	December 19, 1940	December 31, 1941
Antonio Serpa, Jr., M.D.	September 22, 1939	February 29, 1940
Elias Gerbatin, M.D.	February 10, 1939	July 31, 1939
Manoel R. T. Liborio, M.D.	September 22, 1939	January 16, 1941

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ILLUSTRATIONS

INTRODUCTION

Few threats to the future health of the Americas have equaled that inherent in the invasion of Brazil, in 1930, by *Anopheles (Myzomyia) gambiae* Giles 1902. Only the undated arrival of another African mosquito, the vector of urban and maritime yellow fever, *Aedes (Stegomyia) aegypti* Linnaeus, can be considered to have rivaled it in importance.

Warning voices (Shannon 1930, Davis 1931, Souza Pinto 1931, and Soper 1931) emphasized the tragic import of the finding of gambiae in Brazil, but no sustained effort was made to eradicate the species until almost a decade had passed.

Although gambiae gave a small dress rehearsal of its future program in Natal and at several other points in the State of Rio Grande do Norte in 1930 and 1931, it went into its act proper only in 1938 after reaching the Assú and Apodí valleys in Rio Grande do Norte and the Jaguaribe valley in Ceará. The cataclysm of 1938 left nothing to the imagination and gave to the Brazilians a new concept of the possibilities of malaria as an epidemic disease:

> What will be the future of Ceará and Brazil, invaded by *A. gambiae*? The continued presence of this invader amongst us throws a deep shadow on any optimistic prophecies regarding the destiny of our nation (Belo da Mota 1939).

And a veteran student of malaria in many parts of the world, after a three months' survey (May to August 1939) of the gambiae-infested region of Brazil, was led to write:

> There is no doubt that this invasion of gambiae threatens the Americas with a catastrophe in comparison with which ordinary pestilence, conflagration, or even war are but small and temporary calamities. Gambiae literally enters into the very veins of a country and may remain to plague it for centuries.
>
> Even the penetration of yellow fever into the Orient might well be a lesser evil, because its vector is domestic and more easily controlled. When the

medical history of this century is written the result of the contest of health agencies with this preventible invasion will form one of its most interesting chapters (Barber 1940).

The present report will attempt to summarize the most important points in the history of gambiae in Brazil and to describe the organization of the control measures in 1939 which resulted in its eradication in less than two years. It is to be hoped that this "one of the most interesting chapters in the medical history of this century" will not have to be rewritten.

ANOPHELES GAMBIAE IN BRAZIL

1930 to 1940

THE INVADER: ANOPHELES (MYZOMYIA) GAMBIAE[1] GILES 1902

Anopheles of the subgenus *Myzomyia* are quite easily distinguished, as a rule, from *Anopheles* of the subgenus *Nyssorhynchus* known to Northeast Brazil.

The subgenus *Myzomyia* (Edwards 1921) is characterized,

in the imaginal stage, by
bases of fork cells and areas adjacent to cross veins clothed with light-colored scales,
costa with large pale spots,
prosternal hairs generally few, and
male terminalia with four to six spines, none of which are borne on tubercules, at the base of the sidepiece;

in the larval stage, by
antennal shaft with a small unbranched hair,
abdominal palmate hairs generally with a long terminal filament on each leaflet, and
inner clypeal hairs rather widely separated.

[1] Publications on *A. gambiae* previous to 1938 have been summarized by A. M. Evans in the classic *Mosquitoes of the Ethiopian Region*. This summary appeared quite opportunely during the 1938 epidemic of gambiae-transmitted malaria in Northeast Brazil and was most useful to those responsible for the organization of the Malaria Service of the Northeast.

DESCRIPTION OF ANOPHELES GAMBIAE[1]

IMAGO

Female (Frontispiece)

Head.—Scales: pale, generally whitish, slightly yellowish posteriorly in some specimens; frontal tuft very long. Antennae: pale scales on torus and on inner surface of first segment, and occasionally on second and third segments. Palpi: pale bands covering apex, or portion near it of second and third segments, base and apex of fourth, and all of fifth; this last broken in some specimens by a dark ring, resulting in four instead of the usual three pale bands on palpi.

Thorax.—Integument light brown without well-defined markings, mesonotum usually with darker median and two submedian longitudinal stripes; disk clothed with fine creamy or yellowish scales.

Abdomen.—Integument yellowish, appearing darker after engorgement; central as well as dorsal surfaces clothed with yellowish hairs; sternites, principally from second to seventh with submedian pale spots on integument (Plate II, 4); few pale scales on eighth, sometimes on seventh sternite.

Legs.—Spots: variable, some specimens having few, others many, giving speckled appearance, especially to fore and median pairs; spots on femora and tibiae formed by creamy or yellowish scales. Forelegs: distinct white bands covering basal and apical extremities of three segments; basal and, in some specimens, apical band on fourth segment; fifth segment generally dark, sometimes with few yellowish scales. Mid tarsi: first three segments similar to those of fore tarsi, but with narrower pale rings; fourth segment with basal white ring only; fifth segment entirely dark. Hind legs: very narrow light-colored apical rings on first four segments; fifth segment with scattered pale scales.

Wings.—Pale areas of creamy or, in some specimens, slightly yellowish scales with usual disposition as in Plate II (3). Variations

[1] In describing the mosquito as found in Brazil, the authors have drawn upon the work of O. R. Causey and N. Cerqueira who furnished the illustrations on Plates I to V.

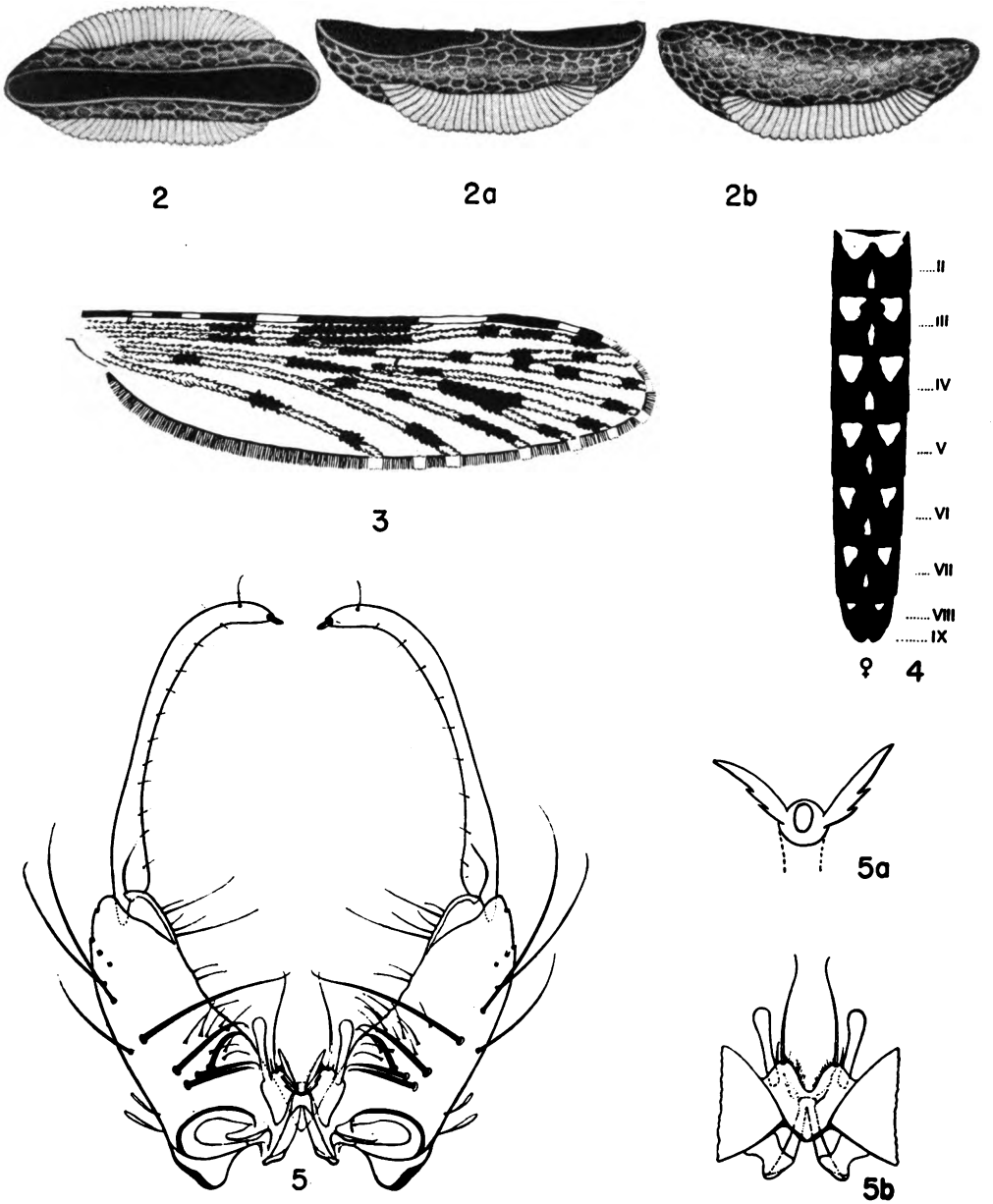


PLATE II.—*Anopheles gambiae*. **2.** Normal egg. **2a.** Abnormal egg. **2b.** Example of extremely abnormal egg. **3.** Wing. **4.** Abdomen of ♀ imago. Note light patches on integument of ventral surface. **5.** ♂ terminalia. **5a.** Mesosome leaflets. **5b.** Claspette (ventral view).

reported: costal vein, either two or three pale spots on basal fourth; second vein, second and third pale spots distinct or in some specimens coalesced to form one large light-colored area; upper branch of fifth vein variable, second pale spot either small or large; sixth vein either two or three dark spots, because subbasal black spot often missing.

Male

Palpi.—Predominantly dark colored, white band at joint of second and third segments; an incomplete white ring on apex of third segment; a white band occupying apical two thirds of fourth segment; apex of fifth segment white, the pale section of fourth and fifth segments not covering ventral surface.

Terminalia.—Sidepiece, five basal spines, mesosome generally four to six pairs of apical leaflets; claspette, bilobed, a club-shaped process on each side, long apical bristle measuring less than twice the length of club, and another much shorter, between apical bristle and club-shaped process (Plate II, 5).

PUPA

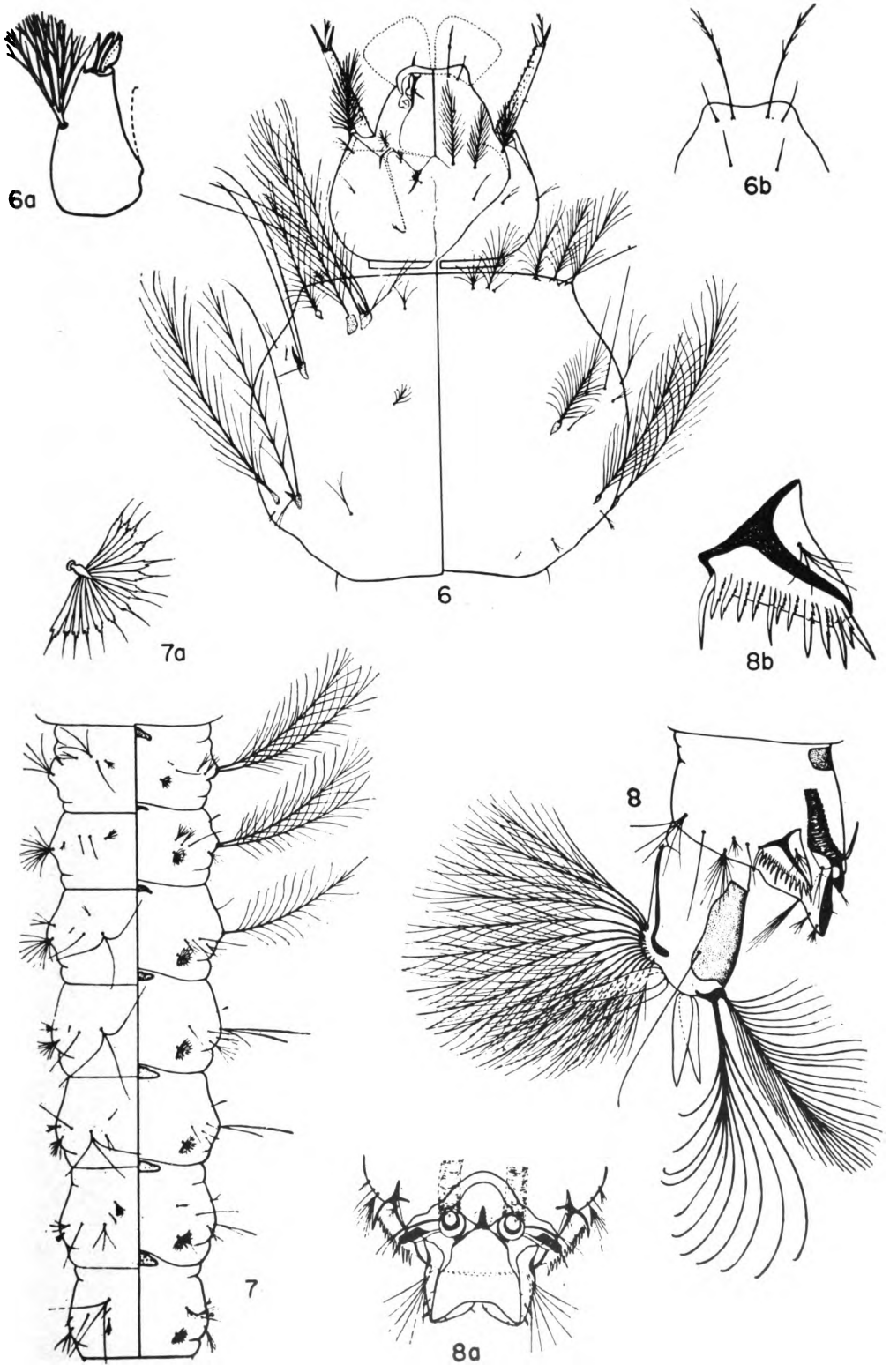
Paddles.—Pear shaped, with short spines beginning at about middle of outer margin, gradually becoming more elongated and replaced distally by fringe of small hairs, with few at inner margin of paddle. Apical hair hooklike, accessory hair slender, simple or two to four branched.

Abdomen.—Hair A of last segment branched, and that of second to seventh segments, spinelike; on fifth, sixth, and seventh segments measuring approximately half the length of segment; on third and fourth segments very short, and second segment, minute.

Hair B on segments four to seven, three to four branched and about two thirds length of corresponding segment.

Hair C simple on segments five to seven and approximately as long as each succeeding segment.

PLATE III.—**6.** Head and thorax of fourth-stage larva (ventral and dorsal views). **6a.** Maxillary palp, showing the palpal hair. **6b.** Clypeal hairs. **7.** Abdomen of fourth-stage larva (ventral and dorsal views). **7a.** Palmate hair of the fourth segment. **8.** Last abdominal segments (lateral view). **8a.** Spiracular apparatus from above. **8b.** Pecten.



Respiratory trumpet.—Meatus well developed, extending one third or more the length of trumpet.

Larva (Plate III)

Head (6, 6a, 6b).—Clypeal hairs delicate, inner long unbranched (or with inconspicuous branches), outer short simple or occasionally bifid; space between inner clypeal hairs at least twice as wide as that between inner and outer hairs of same side. Postclypeal hairs simple, bifid, or three branched. Frontal hairs branched, pale colored. Antennae, small, unbranched hair at one third distance from base to apex.

Thorax (6).—Submedian prothoracic hairs well separated; inner hair, about eight simple (unfoliated) branches, and without chitinous base; middle hair, from eight to twelve branches, and outer hair simple. Palmate tufts of metathorax represented by two- to three-branched hair. Pleural hairs: prothoracic group with two long and simple hairs, one short and many branched hair, another much shorter, simple or two to three branched; on mesothorax both long hairs simple; short metathoracic hair simple or bifid; basal spines rather long on pro- and mesothorax, shorter on metathorax.

Abdomen (7, 7a, 8, 8a).—Lateral hairs: many branched on first three abdominal segments, generally bifid on fourth and fifth segments, two to three branched on sixth segment. Palmate hairs: first segment rudimentary, leaflets few, undifferentiated shoulders; other segments well developed, leaflets many, shoulders serrated and terminating in filament. Tergal plates small and light colored; plate of first segment darker, and that of eighth slightly larger than others.

Pecten (8b).—Teeth, some fourteen or more, five or six of which are long, large, and fine, others serrated on one margin. Saddle hair long, simple.

The above description applies to fourth-stage larvae. Illustrations of first-stage larvae are given in Plate IV (9, 9a). Variations in palmate hairs of the fifth abdominal segment for first-, second-, third-, and fourth-stage larvae are given in Plate V (10, 11, 12, 13). Variations in submedian prothoracic hairs for the various stages are similarly given in Plate V (14, 15, 16, 17).

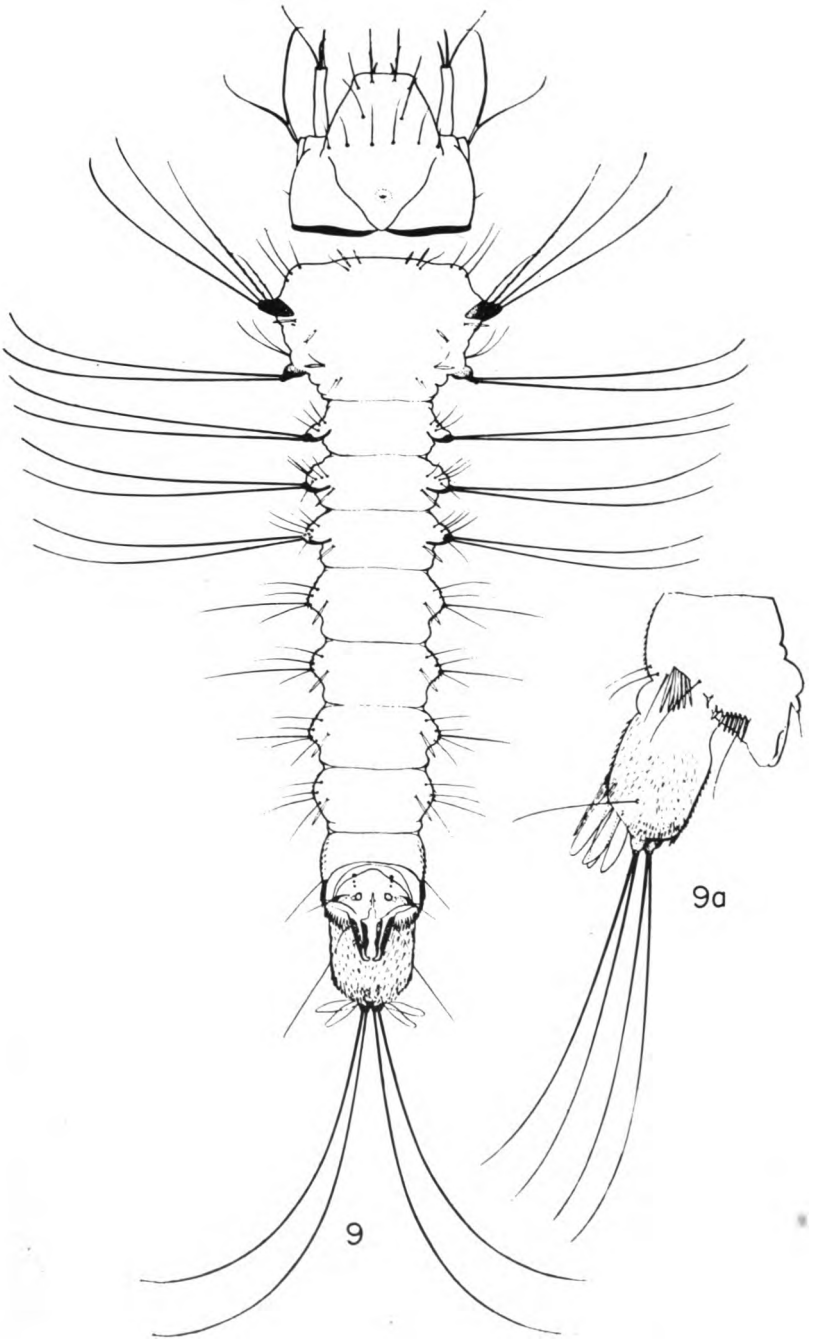


PLATE IV.—**9.** Larva, first stage (dorsal view). **9a.** Last abdominal segments showing pecten of eighth segment and additional pecten.

Egg (Plate II)

The normal egg (2) of second and third generation *Anopheles gambiae* bred in the laboratory does not differ from that described in Africa by Evans and others except that it is slightly longer than that of the African specimen (Deane and Causey). The egg is strongly convex below and slightly concave dorsally, and has a large black elliptical area extending throughout its length and surrounded with a "frill" of the exochorion. In laboratory laid eggs, a small percentage of abnormal eggs was found which could be greatly increased at will by keeping females at 10° or 13°C. for three or more days in the icebox. Abnormal eggs vary from the normal in that the central black elliptical area and the frills are restricted or missing. Many transition forms between the normal and the most extremely abnormal egg were found (2a, 2b).

Variety *Melas*

Although only a pure strain of *Anopheles gambiae* appears to have been involved in the 1930 invasion of Brazil, the *Anopheles* captured on a plane arriving at Natal from Africa in October 1941 was apparently of the variety described under the name *melas* (Barber and Olinger, 1931). Since future invasions may be of either one or the other variety, or both, it seems best to include herewith notes on the *melas* variety.

According to Barber and Olinger, *Anopheles (Myzomyia) gambiae* var. *melas* is very dark, both in the larval and adult stages, some of the imagoes exhibiting the four-banded proboscis. It occurs plentifully in the large coastal swamps surrounding Lagos. According to Evans, the melanic coastal form is "widely distributed in West Africa, having been found also at Freetown, Sierra Leone, besides Gambia and several localities in Nigeria." Laboratory experiments with the two forms of *A. gambiae* indicate that there are important biological differences (Barber and Olinger, 1931). Eggs of the *melas* type develop normally in either fresh or brackish water, while those of the original gambiae fail to develop beyond very small larvae in brackish water. Dark-colored larvae of the original gambiae type are occasionally found where *melas* does not exist.

PLATE V.—10, 11, 12, 13. Palmate hairs of fourth segment of larvae of the first, second, third, and fourth stages. 14, 15, 16, 17. Group of submedian prothoracic hairs in larvae of the first, second, third, and fourth stages.

Breeding Requirements of *A. gambiae*

From the experience of many workers in Africa (Evans 1938), one may summarize the optimum conditions for *A. gambiae* breeding there as: small shallow ground pools, either clear or muddy, free of vegetation, exposed to sunlight, in proximity of human dwellings where the climate is characterized by absence of frost and a range of temperature of less than 40°F. (22°C.).

The word "pool" (Evans 1938) is defined as including puddles and shallow ponds; borrow pits; animal footprints and isolated collections of water in roadside and other drains, ditches, irrigation furrows, seepage areas, and in the drying-up beds of streams or near the edges of lakes and swamps. The shallow overflow from streams or drains may also be an important source of the larvae. Many of the most productive breeding places of gambiae are created by human activities.

The association of breeding places of this species with human habitations was noted by Ross (1910) who observed that gambiae larvae were not found in pools far from human habitations though otherwise favorable. In the Anglo-Egyptian Sudan also, the Medical Service reported (1936) that the distribution of gambiae was found to be very uneven and indicated localization of breeding around certain centers of human habitations. In the remainder of the area examined, although ideal conditions, such as stagnant pools were seen, none were infested with larvae.

Lamborn (1925) noted that *A. gambiae* in Nyasaland is as particular in the selection of its breeding places as any oriental species of anopheles and he thought it "improbable that the insect, however hard pushed as to its ordinary breeding places, would make use of water in which its larvae did not usually occur."

Gambiae larvae, however, usually occur in such a variety of breeding places that Symes (1940-41) was led to report:

> It is easier to define types of water in which gambiae will not breed than to list all those in which it will. It will not generally breed: (1) in heavily shaded water; (2) in fast-running water; (3) in very dirty water such as one finds in some partially dried-up pools at the end of the summer; and (4) in very alkaline and/or polluted water.

Although shade and vegetation are usually deterrent factors

(Ingram and DeMeillon, 1927), larvae of gambiae have been reported in muddy stagnant water, partially shaded by reeds and containing algal growths, which was constantly disturbed by wading cattle; the larvae were numerous in shaded and unshaded parts alike. The same authors found gambiae larvae on several occasions among masses of floating vegetable growth at the edge of the open water on the Hluhuwe River. In the Sudan (Report of the Sudan Medical Service for the year 1936) after the rains began, gambiae larvae were found in grassy pools rather than in irrigation channels.

It is the consensus of opinion in Africa that gambiae does not breed actively in artificial containers. Ingram and DeMeillon say that it is rarely found in artificial collections of water, such as earthenware pots or in tree holes. Symes reports, based on work in East Africa, that gambiae was found in barrels and tanks only on ten occasions during ten years. Ross (Freetown, Wilberforce, 1899) gives a single instance of breeding, in an old tub full of green water weed.

Larvae of the *melas* variety of gambiae have been found in pools which have fresh water in the rainy season but have as much as 46 per cent sea water during the dry season (Barber and Olinger, 1931). *A. (Myzomyia) gambiae* itself, on the other hand, is a freshwater breeder.

In Brazil observations on gambiae's preferred breeding places have closely paralleled those of the African workers but have continued to emphasize the high selectivity of the species during the dry season in contrast with its much more general distribution during the rainy season. Shannon first found gambiae breeding in shallow grassy pools during the rainy season (March 1930), but on a second visit to Natal at the end of the dry season (December) of the same year, found larvae of this species only in seepage outcrops and in shallow pools fed by such seepage water. After an extensive dry season survey of the situation in 1938, Shannon and Andrade (1940) came to the following conclusions:

> An analysis of observations on the types of water deposits favored by gambiae shows that nearly all of the larvae found were in small or shallow collections of sun-exposed ground waters. These usually had a surface area of less than two square meters and a depth of twenty centimeters or less. On occasions

when they were found in larger bodies, the larvae were in the more shallow portions, in a depth of ten centimeters or less. Most of the infested pools were entirely free of vegetation and when plants were present, the greater portion of the surface consisted of free water.

Surveys on the upper Jaguaribe River, Ceará, during the dry season of 1939, led to the statement (Barber 1940):

The bulk of the gambiae is produced in small pools, algae free or with the surface free, not connected with the main stream; some gambiae larvae, however, occur among algae in the stream itself. These side pools are formed by animal tracks in the wet sand, by well-pits dug by the people for water supply ("caçimbas") and by pools isolated by the falling stream. . . . Less common, but highly prolific of gambiae, are river bed pools containing iron hydroxide and the remains of iron bacteria, animal wallows in the muddy flats and seepage pools formed by small springs in the river banks. . . . In and near the lagoons we found gambiae in only two places . . . in both cases in the rice fields bordering the lagoons.

In one of these fields the rice had been harvested, exposing the water to the sun, while in the other small pools formed at the borders of the growing plants. Gambiae was not found in the shade nor in thick upright vegetation, nor in lagoons with Azella, Lemna, Salvinia, Marsilea, or Mimosa, species of plants favoring the larvae of *Nyssorhynchus.*

In the carnauba flats of the lower Jaguaribe valley, gambiae was found breeding in large numbers in muddy, stagnant, partially shaded pools, oftentimes with algae, frequented by both hogs and cattle.

As in Africa, gambiae breeding has rarely been noted in water tanks and domestic utensils in Brazil. The late E. Chagas reports observations on a tank at Timbaúbas, in which only culex larvae were observed during the rainy season when gambiae larvae were present in the ground pool formed at the base of the tank. During the dry season, however, when the ground pool disappeared, larvae of both culex and gambiae were found in the tank.

A study of gambiae throughout the rainy season of 1940 at Cumbe, near Aracatí, Ceará, led to the following report (Causey):

Although gambiae larvae were found in greater proportion in collections with no visible vegetation, they were often discovered in collections with algae (especially in ditches and borrow pits) and occasionally in temporary pools

with grass. . . . Larvae were never found breeding in water with lilies and were found only once in an irrigation ditch covered with Pistia. During the dry month of January, water collections with no vegetation were found positive for gambiae larvae in a larger percentage of examinations than were collections showing some or much vegetation. With the advancing wet season and increased gambiae breeding places, a large proportion of water accumulations with more or less vegetation harbored gambiae larvae. Notwithstanding, considering the period as a whole, bodies of water without vegetation were found to furnish the preferred breeding places. . . . Larvae were seldom found in very shaded collections of water. . . . A fair number were found in partially shaded water collections.[1]

During the first five months of 1939 before the antigambiae campaign had altered appreciably the conditions of breeding, field workers of the Malaria Service of the Northeast in the State of Rio Grande do Norte reported finding gambiae in: collections of water without vegetation, 1,164 examined, 41 per cent positive; collections of water with vegetation, 589 examined, 24 per cent positive. As to the breeding places with vegetation, gambiae was ordinarily found where the vegetation was sparse, rarely being encountered amid a thick growth; in large bodies of water it was found near the margins or in the marginal depressions, such as hoofprints. On the other hand, just the reverse was found for the *Nyssorhynchus* which seemed to prefer the middle of large bodies of water and thick vegetation.

During the rainy season gambiae tends to breed almost everywhere except in heavily shaded pools, in running water, in pools completely covered with vegetation, and in deep water. Even pools with very dirty, very alkaline, or very polluted water, may from one day to the next become favorable for gambiae production after fresh rains. As Barber (1940) has pointed out there are unhappily few or no antilarval substances which are not neutralized by dilution and places unsuitable to gambiae in the dry season may become quite favorable during heavy rains. These rains are responsible for the appearance of gambiae in pools formerly devoid of breeding, by rendering the water suitable, and also, mechanically, by bringing in larvae and eggs from permanent breeding places.

[1] Whereas 42 per cent of three hundred unshaded water collections contained gambiae, only 1 per cent of over two hundred shaded, and 7 per cent of almost four hundred partially shaded collections were found with gambiae.

The Brazilian observations of seasonal variation in type of breeding place in which larvae of gambiae are found form a basis for an understanding of the disparity existing among the African observations and at the same time justify the conclusion that gambiae conforms to the general rule that every species of anopheles, in spite of tendencies to spread into unusual breeding places, is restricted in its multiplication and distribution by an adaptation to certain types of surface water in which alone it can breed in effective numbers (Hackett, *et al.,* 1938).

The fundamental biological differences which exist between gambiae and the native Brazilian anopheles, reflected in their choice of breeding places, are especially notable under dry season conditions when, "because of the general scarcity of breeding sources and the absence of intermediate types of water collections, the different species are forced to choose the type most favorable for their development" (Shannon 1932).

In conclusion, then, it can be said that gambiae, as observed in Brazil and in Africa, breeds most effectively in small shallow sunlit pools of fresh water without vegetation.[1] The special adaptation of gambiae to this type of breeding place, which is almost universally present where man and his domestic animals are found, is quite out of keeping with the behavior of most other anopheles and is, undoubtedly, an important factor in its widespread distribution in the Ethiopian region and in its success in establishing a foothold in Brazil.

Duration of Viability of Gambiae Eggs

The ability of eggs of a given species of mosquito to remain viable after long periods of desiccation is an important factor which must be taken into consideration in a campaign for eradication. Species such as *Aedes aegypti* whose eggs remain viable after many months' desiccation are especially difficult to eradicate. The duration of viability of the eggs of gambiae was studied in Mauritius (Gebert 1937) where it was found that 25 per cent of *Anopheles*

[1] Eggs of gambiae in the laboratory colony of the Malaria Service of the Northeast hatched in water having as much as 2 per cent sodium chloride, but adults failed to emerge when eggs were placed in solutions of more than 1 per cent (Causey).

gambiae eggs remained viable twenty-four to forty-eight hours after the concrete basins in which they were placed had been drained. Very few eggs hatched after seventy-two hours and none after longer periods.

In Ceará, where the majority of pools during the dry season were in slowly drying sandy river beds, experiments were carried out to determine the viability of *A. gambiae* eggs conserved at constant humidity in moist sand or exposed to spontaneous drying in sand or mud. In the earliest experiments in Ceará (G. O. Castro), some 12 per cent of 1,250 eggs kept for 10 days on moist filter paper at room temperature hatched. Later work (Deane) with batches of 2,000 or more eggs stored in moist sand for 8, 10, and 12 days gave 36, 27, and 8 per cent of live larvae respectively, whereas batches stored for 14, 16, and 18 days gave less than 1 per cent hatching, and no live larvae were forthcoming from batches stored for longer periods. Viable eggs were found in greater percentages among batches stored in drying sand; 72, 58, and 26 per cent of live larvae were obtained from batches stored in drying sand for 8, 10, and 12 days respectively and 1 per cent of hatching was recorded for 18 days' storage.

Feeding and Resting Habits

Of the 180 odd species (of anophelines) which may be considered potential vectors, since all that have been tested easily become laboratory hosts of the malaria parasite, the great majority are rendered comparatively harmless in nature because their biting habits do not bring them into frequent and especially repeated contact with man (Hackett, *et al.*, 1938).

A. gambiae is not of this great majority, but is probably the most domestic of all anopheles and the one which feeds most consistently on man. As Symes (1940-41) says:

. . . *A. gambiae* is almost truly domesticated. It feeds with ease and luxury upon the all too available humans and breeds prolifically and with equal ease in conditions provided by these considerate hosts. Its meals are served in the dining room, sitting room, and bedroom and on the verandah and its breeding places are provided a few yards' flight away in puddles, irrigation canals, and ditches in the garden, in the ditches at the roadside, in a murram pit or quarry near by, or in stagnant streams or equally stagnant canals of

the swamp. It is not surprising that one mosquito has taken advantage of these amenities; it is surprising that many other mosquitoes have not done the same.

The requirements of gambiae for the microclimate of its resting places have not been adequately determined, but it is known that a low humidity is prejudicial at high temperatures. It is a shelter-loving mosquito, seeking by preference the darkest and worst ventilated rooms in the darkest houses (Evans 1938). It has been captured in natural outdoor shelters by various workers in Africa (Evans 1938), and the following findings at Nairobi in 1931 led Symes to state that *A. gambiae* adults harbor in large numbers in long grass and brush,

	♂	♀
beneath rock or stones	116	117
in long grass	74	66
at base of tree trunks	50	56
beneath the earth banks	121	117
other cavities	18	16
	379	372

Blacklock and Wilson (1941) reported finding gambiae resting on shrubs in the daytime in Freetown. In Brazil, however, such attempts as were made by Barber, Causey, and others to find gambiae gave negative results. Perhaps this could be explained by the fact that the region in which gambiae spreads in Brazil is one of glaring sunlight, steady wind, shimmering heat, and sparse vegetation, so that there are few sheltered outdoor resting places.

Kerr (1933) found gambiae biting freely out of doors in Nigeria, but in Brazil no outdoor biting was registered. Causey reports, on the basis of 129 hours of outdoor captures during February, March, and April, 1940, that experiments using both animal and man as bait, inside and outside of houses, revealed that *A. gambiae* rarely, if ever, feeds outside and that man constitutes the preferred host.

Even when captures were attempted with animal and human bait right outside of houses teeming with gambiae, it was never possible to catch gambiae outdoors. Areas close to breeding places also yielded negative results.

Gambiae seems to be essentially anthropophilic. In Africa, where cattle are housed under the same roof as human beings, Symes (1930) reports 82.3 per cent of gambiae engorged with human blood. In Northeast Brazil, where animals are not quartered in buildings, practically the only shelters available to gambiae are human dwellings, and there it feeds almost exclusively on man.

Causey states that the number of gambiae to be found in a given house depends upon the presence or absence of human occupants and upon the light intensity of the interior. Of these, he attributes most importance to the human factor. Even at the height of the mosquito population, only a few isolated specimens, practically all males, are found in vacant houses. The rapidity with which uninhabited houses become reinfested when reoccupied, and again abandoned by gambiae when vacated, seems to demonstrate clearly the importance of the presence of human beings.

Experiments, using goats, were conducted in some of these temporarily uninhabited houses. Although in eighteen captures, only five male mosquitoes had been found in the houses while vacant, seven males and twelve females were found in thirteen captures when the houses were occupied by goats, and thirty-seven males and 272 females were found in fifteen captures in the same houses when occupied by humans.

In Nigeria, Kerr (1933) made studies of the biting habits of gambiae and found that in all-night catches the peak of biting activity occurred between 2 A.M. and 4 A.M., which was also found to be true for Brazil in experiments carried out by Causey in Cumbe and E. Chagas in Gracismões.

The appetency for human habitations of gambiae in search of shelter and blood meals has undoubtedly been a factor in its ability to spread from place to place, for gambiae has been reported in boats, trains, automobiles, and even airplanes, all of which may be classified as human habitations. The transatlantic passage, as described on page 21, can best be deduced on the basis of this characteristic, and many extensions of the breeding range of gambiae in Brazil, to be mentioned later, can be satisfactorily explained only on the basis of the accidental transportation of adults from one point to another by means of human conveyance.

Gambiae as a Vector of Malaria

In marked contrast to the native anopheles of the gambiae-invaded part of Brazil, which enter human habitations less frequently and feed freely on animals away from human habitations, *A. gambiae* is the outstanding example of an anopheles which has adapted itself completely to living on and with the human race. Although gambiae has a high susceptibility to infection with the various parasites of malaria, its great capacity for causing epidemic malaria is in large part due to its almost exclusive habit of resting and feeding indoors. Since the preferred places of *A. gambiae* are of a type often found close to human habitations and, in many places, are created by human activity, its life cycle is often completed within a very small radius of the home of its victim.

In this respect gambiae bears the same relation to malaria that *Aedes aegypti* does to yellow fever. Not necessarily possessing a greater innate capacity for transmission of yellow fever virus than that possessed by certain other mosquitoes, aegypti is nevertheless the most dangerous vector of this disease because its life cycle is generally completed in the home. The importance of domesticity in maintaining close and constant contact between a disease vector and the human victim can hardly be overrated. Yellow fever in the presence of the domestic *A. aegypti* is a fearsome plague among nonimmune populations, whereas yellow fever as a jungle disease loses much of its terror for the population as a whole, since only those who must go into the forest become infected. Aegypti-transmitted and jungle yellow fever, although the same disease, are so different epidemiologically that even after the existence of jungle yellow fever had been amply proven by modern laboratory methods, many workers familiar with yellow fever as an urban epidemic disease were unwilling to accept the idea of the jungle disease. In the same way, even though malaria is not entirely unknown in many parts of the gambiae-invaded region of Northeast Brazil, the people and, in the beginning, even many members of the medical profession, could not believe that the calamity they were observing was caused by malaria.

In Africa, *Anopheles gambiae* is one of the two principal vectors of malaria and is the only important one in certain regions where

A. funestus is absent (Evans 1938). The evil reputation of the Dark Continent as the white man's grave is in large part based on the exceptional activity of gambiae. "In Africa, malaria takes pride of place as chief impediment to European colonization. . . . *Anopheles gambiae* Giles (is) the best known, most dangerous, and widely spread carrier of malaria in the whole of Africa" (Manson 1941).

From Dakar, in the West, to Italian East Africa (Corradetti 1939), from Abyssinia, in the North, to Natal, South Africa, malaria is a serious endemic problem wherever conditions permit gambiae to breed freely; serious epidemics occur where generally unfavorable conditions under which gambiae can exist become more favorable.

Sporozoite indices obtained by the workers in Africa in dissections carried out over a period of thirteen years, vary from 13.1, found by Barber and Olinger in Ibadan, Nigeria (1931), to 0.46, reported by Symes in Nairobi (1940-41).

The range of variation in sporozoite indices found in Brazil is also very wide (Table 1): from 30.2 (Davis) and 28.2 (Souza Pinto) in Natal and environs in 1930-31, to 1.6 registered in 1940 by Causey in Cumbe, Ceará. The rates for gambiae found by Davis (pp. 52-53) and Souza Pinto (p. 56) are extremely high and can be attributed to the fact that these workers were dealing with mosquitoes captured during the height of malaria outbreaks at the beginning of the dry season after the peak of gambiae production had passed. On the other hand the studies at Cumbe were limited to the wet season when gambiae production was excessive and sporozoite indices tended to be low because of the larger number of very young mosquitoes in each group examined. Barber, dissecting specimens caught between May and August, 1939, in thirteen different localities in Ceará, found a sporozoite index of 2.7 in 613 glands. E. Chagas and his collaborators, working in the rural areas of Russas, Ceará, found a natural infection rate of 4.0 in 1,000 glands. By careful adjustment of collections of adult gambiae as to both space and time from places and periods of variable productivity, it should be possible to get almost any sporozoite index desired.

TABLE 1

DISSECTION OF ANOPHELES (M.) GAMBIAE GILES AND VARIOUS SPECIES OF NYSSORHYNCHUS, IN BRAZIL

SPECIES OF ANOPHELES	SOURCE	LOCALITY	MOSQUITOES DISSECTED								
			Total			Salivary Glands			Stomachs		
			Number	Positive	Percentage	Number	Positive	Percentage	Number	Positive	Percentage
GAMBIAE	Davis May 1930	Natal, Rio Grande do Norte	172	108	62.8	172	52	30.2	172	102	59.3
	Souza Pinto July and August, 1931	Taipú and São Gonçalo, Rio Grande do Norte	—	—	—	397	112	28.2	397	284	71.5
	E. Chagas 1939	Russas Ceará	—	—	—	1,000	—	4.0	1,000	—	38.7
	Barber May to July 1939	Ceará (13 localities)	613	—	—	600	—	2.7	333	—	9.3
		Aracatí	—	—	—	42	—	10.0	—	—	—
	M. Ferreira January to April, 1939		—	—	—	121	—	2.4	128	—	3.9
	Causey January to April, 1940	Cumbe Ceará	1,891	105	5.6	1,838	29	1.6	1,833	87	4.7
DARLINGI	Davis 1930	Belém Pará	200	44	22.0	181	9	5.0	197	44	22.3
	Davis and Kumm, 1931	França Baía	240	69	28.7	215	16	7.4	240	66	27.5
	Shannon 1933	Porto Velho Amazonas	56	—	—	—	1	1.8	—	5	9.0
AQUASALIS	Causey 1940	Cumbe Ceará	201	3	1.5	190	1	0.5	186	2	1.1
	Causey 1941	Beirada Ceará	—	—	—	391	0	0.0	373	0	0.0
ALBITARSIS	Kumm 1932	São Salvador Baía	—	—	—	48	0	0.0	240	14	5.8
	Causey 1940	Cumbe Ceará	314	0	0.0	295	0	0.0	292	0	0.0
	Causey 1941	Beirada, Ceará	—	—	—	67	0	0.0	64	0	0.0
		Camatuba River	201	1	0.5	—	—	—	—	—	—
OTHER ANOPHELES	Causey 1941	Camatuba River	49	0	0.0	—	—	—	—	—	—

It is difficult to establish a comparison of the natural rates of gambiae infection with those of the *Anopheles* of the *Nyssorhynchus* group which, before the introduction of gambiae, were the principal malaria vectors in Brazil, because dissections of mosquitoes of this subgenus have been very limited. *A. (N.) darlingi*,[1] the most dangerous of Brazilian anopheles (Barretto 1938, Galvão 1937), has not been found in the area invaded by gambiae, but results of dissections of this mosquito in other parts of Brazil are available. In April 1930, examination of *A. darlingi* in Belém, Pará, during an outbreak of malaria, gave an infection rate for this species of 5 per cent, 9 glands being found with sporozoites in 181 examined (Davis 1931). In February 1931, examination of darlingi captured in França, Baía, also during a malaria epidemic, showed 16, or 7.4 per cent, of 215 salivary glands infected (Davis and Kumm, 1932).

In so far as the data are comparable, the results of dissection agree with epidemiological experience in rating gambiae as a much more efficient vector of malaria in nature than are any of the Brazilian *Anopheles*.

THE REGION INVADED

DATE AND ROUTE OF INVASION

When in March 1930, Shannon (1930) collected approximately two thousand larvae of *Anopheles gambiae* at Natal (Fig. 1) "in a small overflowed grassy field lying between the railroad track and the Potengí River," the smallness of the area infested suggested that this mosquito was a recent importation, while its location pointed to the development of rapid mail service with Europe via Africa as probably responsible for its importation. The manner of its arrival cannot be proven but it would seem doubtful that any of the three airplane flights between Africa and Natal

[1] Studies made during the campaign against gambiae, carried out by the Malaria Service of the Northeast and reported elsewhere (Causey 1942), show that darlingi may be highly domestic in one area and not in another, and that *A. aquasalis* and *A. albitarsis* may be found in considerable numbers inside the house.

FIG. 1.—Site of original gambiae breeding, in Natal.

made before March 23, 1930, could have been responsible. These flights were all by land planes and the airfield lies some seven kilometers from the point on the river bank where gambiae was discovered. No gambiae foci were ever found close to this field.

In July 1928, sixteen months after the first and nine months after the second of these flights, no less an authority than Lutz studied the mosquitoes of Natal during a survey of various proposed sites for the construction of a leprosarium. Lutz called the attention of the local authorities[1] to the possibility of insect importation from Africa, consequent upon the development of rapid transportation, but failed to find any evidence of such importation.

The third flight (Mermoz), from Saint Louis de Senegal to Natal on March 12 and 13, 1930, anteceded Shannon's discovery by only ten days, a period entirely insufficient to account for the extent of gambiae breeding found.

It seems almost certain that some time late in 1929 or early in 1930 gambiae crossed the Atlantic on one of the fast "avisos" (destroyers) of the French Government, which made the mail run

[1] Dr. Juvenal Lamartine, ex-governor of the State of Rio Grande do Norte. Personal communication.

of 3,300 kilometers between Dakar and Natal in less than one hundred hours. Not only did these destroyers anchor within a kilometer of the first breeding place of gambiae found in Natal, but their anchorage in Dakar was also within easy flight range of gambiae from the shore. As the water supply of the avisos was carried in sealed tanks, it is probable that this species made the transatlantic crossing in the adult stage.

NATAL, BRIDGEHEAD OF INVASION

That the invasion of Brazil by gambiae did not have much more serious consequences during the six or seven years immediately following its discovery is owing in large part to the unfavorable topography of Natal, the port of entry, and of that part of the State of Rio Grande do Norte immediately contiguous to it. Likewise, the disastrous events of later years can be attributed to the more favorable conditions existing in the Assú and Apodí valleys of Rio Grande do Norte and in the even more important Jaguaribe valley in the State of Ceará (Fig. 2).

The environment of Natal itself is not highly favorable to gambiae. Natal, a city of some thirty-five thousand people (1930) and the capital of the State of Rio Grande do Norte, lies on the right bank and at the mouth of the Potengí River. The port of Natal, formed by the river itself, is protected from the ocean by a coral reef. Most of the city, except the port and a fishing suburb, lies on a high sandy plateau extending from the river to the sea, where it ends in precipitous bluffs. This plateau stretches for a considerable distance to the south and southwest of Natal and was probably an important factor in preventing the spread of gambiae southward along the coast to the well-watered region about São José de Mipibú. Since the plateau also forms the right bank of the Potengí River there is naturally very little opportunity for anopheline breeding, the river water being mixed with sea water by the tides. Had it not been for man-made dikes built along the river front to transform the salt-water tidal flats into fresh-water hayfields, gambiae might well have failed to secure a bridgehead on the American continent.

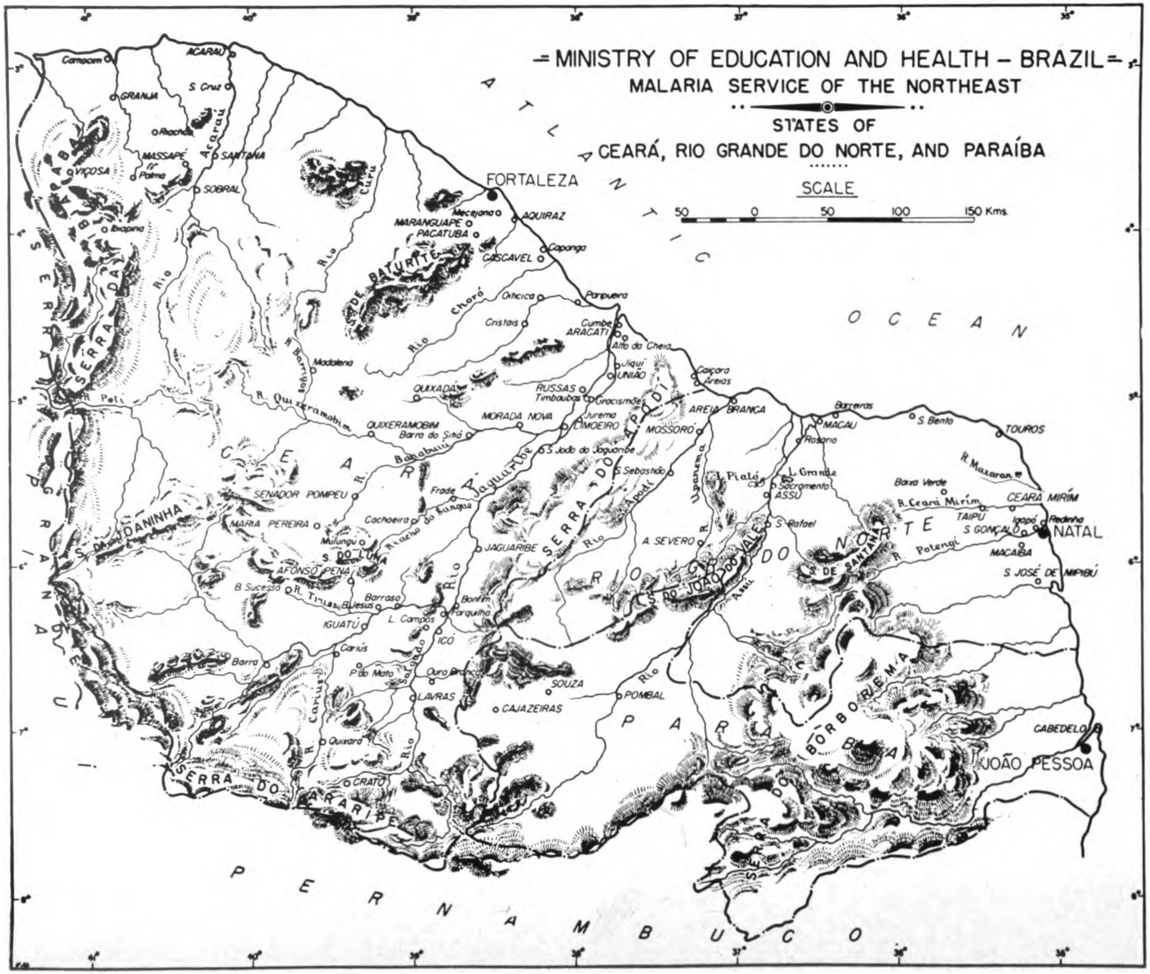


Fig. 2.—Upper Northeast Brazil.

Possibilities of Spread from Natal

By infiltration.—To the south of Natal and at a comparatively short distance, is a well-watered coastal plain extending by easy stages into the coastal plains of Paraíba and thence to Pernambuco and Alagôas. South of Natal, the coastal plain of Northeast Brazil receives a much heavier rainfall and in this particular offers much more favorable opportunities for the production of anopheles than does the coastal plain to the north and west. However, the type of stream found south of Natal is less suitable for gambiae breeding, as it is swiftly flowing, with deeply shaded banks. Furthermore, to reach this well-watered coastal plain from Natal, the invader would have had to cross a tableland quite unsuited to anopheles production which, although comparatively limited in extent, nevertheless seems, by great good fortune, to have been a sufficient barrier. Just to what extent the effectiveness of this barrier may have been owing to the fact that progress across it would have to be counter- or crosswise to the prevailing southeast trade-winds is uncertain.

Immediately to the west of Natal the mountains, which are unfavorable for the breeding of gambiae, come fairly close to the coast, leaving a relatively narrow coastal plain open to the north and northwest. In this coastal plain there are several small river valleys, the most important of which, that of the Ceará Mirím River, is highly developed for the planting of sugar cane, the necessary year-round supply of water being secured through irrigation.

Following the coastal plain around the northeast corner of Rio Grande do Norte, are long stretches of barren country with but little population and that little is concentrated in villages along the coast. It is only in the western part of this plain in the lower reaches of the Assú and Apodí rivers that opportunities for extensive gambiae production are again encountered. The Apodí River valley is separated from the Jaguaribe River valley in the State of Ceará by the Chapada do Apodí, a high wide plateau, which extends almost to the sea between the two and is entirely unsuitable for the breeding of gambiae.

Once the invader passed around or over this barrier, it encoun-

tered much more favorable conditions and an unexcelled opportunity to spread to the interior both through infiltration along the Jaguaribe River valley and by means of artificial transportation. This river and its tributaries offered direct access to approximately one half the area of the entire State of Ceará, including the important well-watered districts about Iguatú and those near Crato at the foot of the Chapada do Araripe.

Likewise the coastal plain of Ceará, between the Apodí mountains and Fortaleza, offers favorable opportunities for direct spread to the well-watered region around the capital of the state. From Fortaleza westward the coastal plain at certain points affords very highly suitable conditions for gambiae breeding.

It is apparent from the foregoing that the State of Rio Grande do Norte is much less favorable than is eastern Ceará to the rapid dissemination of gambiae by infiltration.

By transportation of imago.—From the standpoint of transportation, on the other hand, Natal is an excellent point for gambiae dissemination. It is an ocean port which receives international and coastwise steamships, as well as small sailing vessels which touch at many little fishing villages on the coast. It is the terminus of two railway lines, both of which pass through country favorable to gambiae production: one, connecting Natal to the capital of the State of Paraíba to the south, passes through the well-watered coastal plain; the other, serving the interior of the State of Rio Grande do Norte, passes through the rich Ceará Mirím valley. Natal is also the center of a network of truck transportation and although the main highway connecting the port with the neighboring states, both to the south and to the west, passes through a dry mountainous region, highly unsuited to gambiae breeding, automobile transportation could easily aid in extension along more favorable roads.

During the dry season, automobile and truck travel proceeds from the Apodí to the Jaguaribe valley in Ceará, either crossing the Apodí mountains or following the coast at low tide, and once the Jaguaribe valley is reached, even better transportation facilities exist. An excellent highway connects the upper reaches of this valley with Fortaleza. Likewise, the upper valley and several of

the tributaries of the Jaguaribe, including the Salgado River above Icó, are cut by a railroad line and its feeders, the main terminus of which is Fortaleza. Only in point of ocean transportation is the eastern section of Ceará less favorable than Natal for gambiae dissemination. But even here there is no lack of small sailing ships working in and out of the mouth of the Jaguaribe River and other points along the coast right up to Fortaleza. Fortunately, so far as is known, gambiae made no large single jump of hundreds of miles from any infested point in Brazil, similar to that which brought it to Natal from Africa.

TOPOGRAPHY OF NORTHEAST BRAZIL

In considering the topography of upper Northeast Brazil as a whole, it will be seen that only a comparatively small part of the total surface of the three states included therein, Paraíba, Rio Grande do Norte, and Ceará, is suitable to the large-scale production of gambiae.

The term Northeast Brazil (Waring) has been used to designate the extensive areas from Piauí to Baía between the 3rd and 13th degrees south latitude, with a climate, except along certain parts of the coastal plain, more arid than tropical. Northeast Brazil is, geologically, a degraded zone where the ancient plateau in large part has been worn down to the crystalline skeleton. The erosion of this plateau has been far from uniform, with the result that the three states forming the shoulder of Brazil, which are of especial interest in connection with the study of gambiae, Ceará, Rio Grande do Norte, and Paraíba, are almost completely blocked off from the rest of Northeast Brazil by plateaus and mountains, except where the coastal plain extends to the south into Pernambuco and to the west into Piauí (Fig. 3). These states, lying between the 3rd and 8th degrees south latitude and covering approximately 257,000 square kilometers, make up the northeastern slopes of the great Brazilian plateau with a series of terraces facing north, northeast, and east, formed by the denudation of the ancient sandstone plateau which once covered this part of the continent.

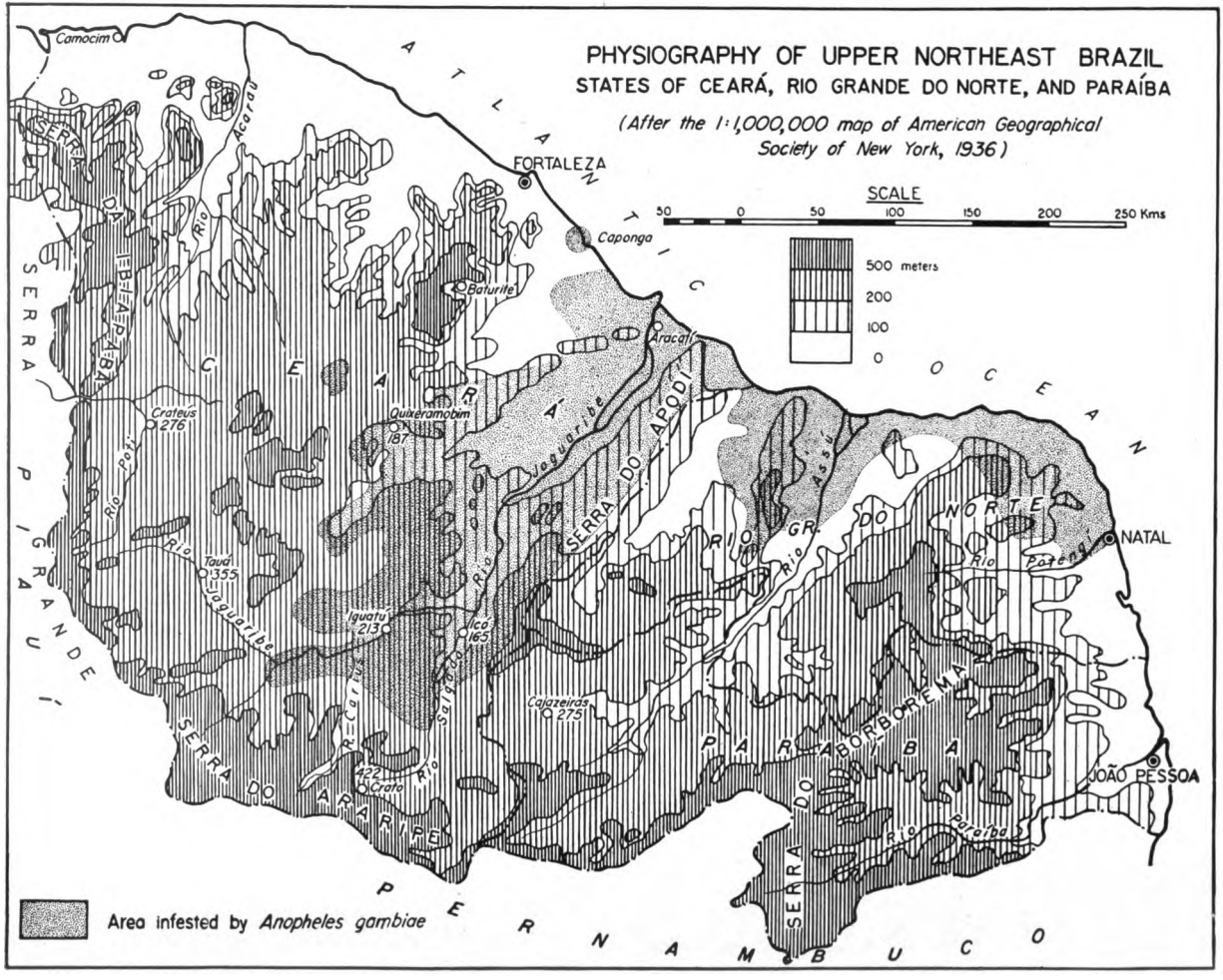


FIG. 3.

Terrain

Three distinct zones may be pointed out in this region: the mountains, the lower plateaus of the interior, and the coastal plain.

Mountains.—The mountains and tablelands, varying in altitude from four hundred to eleven hundred meters, are the remnants of the ancient plateau which, through surface erosion, has been laid bare down to the Archean basement. There are, however, three main mountain ranges in the states under discussion which are still capped with complexes of sandstone alternating with thin layers of limestone (Oliveira and Leonardos, 1940). These are the Ibiapaba mountain range and the Araripe plateau, which bound Ceará on the west and south, and parts of the Apodí plateau which is the watershed between the Jaguaribe and the Apodí river valleys on the boundary between Ceará and Rio Grande do Norte.

The soil of these three ranges absorbs much of the rainfall which they receive, but practically all the other mountains are dry and rocky and entirely unsuited to conserving water. Except for a thin layer of porous soil, resulting from the decomposition of the surface, water does not penetrate this terrain but rushes in torrents down the narrow rocky valleys during the rainy season. Even the thin layer of porous soil permits rapid evaporation and the little moisture retained quickly disappears.

Lower plateaus.—The terrain of the major portion of the States of Ceará and Rio Grande do Norte slopes gently from the mountain masses to the coast. Much of it ranges from 100 to 300 meters above sea level, but it is broken in many places by hilly ranges or isolated hills, some with sharp, others with gently rounded profiles (Pompeu Sobrinho 1916). Lying between these hilly ranges are broad shallow river valleys which carry the flood of water during the rainy season, drying up completely shortly thereafter. The main exceptions are the Jaguaribe River, which drains almost half of the area of the State of Ceará, and the Apodí and Assú rivers in Rio Grande do Norte, whose subsurface water sheet, even during the height of the dry season, allows of conditions which greatly favor gambiae production.

Coastal plain.—The coastal plain, which is from three to twenty-five kilometers wide and rarely rises more than one hundred meters

above sea level, is composed of clays and soft low limestone cliffs, as well as sand dunes (Small 1923, publ. 32). All along this coastal plain seepage areas extremely favorable to gambiae breeding occur.

Drainage System

Except for a small section of western Ceará which drains into the Parnaíba valley through the Boqueirão do Potí (Small 1923, publ. 25), the drainage of this region, following the slope of the terrain to the coast, is entirely independent of that of the rest of Brazil. Likewise, the drainage system of Ceará is completely independent of those of Rio Grande do Norte and Paraíba which have some valleys in common.

In each of the States of Rio Grande do Norte and Ceará there are two main river valleys and a coastal section which is drained by small short rivers. In Rio Grande do Norte it is the eastern third which is drained by short coastal rivers rising in the easternmost mountains of the Borborema range and running eastward to the sea (Crandall 1923). These are all relatively unimportant, including the Potengí and the Ceará Mirím, which are somewhat larger than the others. The state's most important river, the Assú, draining its central section, rises beyond the southern border, in the State of Paraíba, and runs in a northeasterly direction to the northern coast. Parallel to the Assú, and separated from it by the João do Vale mountains, runs the Apodí River which drains the western third of the state.

Across the Ceará boundary, on the other side of the Apodí range and paralleling the course of the Assú and Apodí rivers, lies the largest river of all the gambiae-infested area, the Jaguaribe, which, together with its tributaries, drains all the southern, central, and eastern sections of the state. The Acaraú River, the second largest in Ceará, drains the western section of the state at the foot of the Ibiapaba range, while small relatively unimportant rivers drain the central coastal area.

As has been mentioned above, most of the terrain is practically impermeable, with the exception of the sediment-covered mountain ranges (Ibiapaba, Araripe, and to a lesser extent Apodí), the sandy plains in the river valleys, and the coastal plain. Even

FIG. 4.—River bed agricultural production during the dry season.

FIG. 5.—Gambiae and sweet potatoes grow side by side.

FIG. 6.—Gambiae breeding in drying caçimba (shallow well).

FIG. 7.—Shaded caçimba.

FIG. 8.—Washing clothes at caçimba.

the alluvial plains in the lower river valleys, away from the river banks are of clay which does not permit much absorption, and water collecting here after floods and rains disappears only by evaporation.

As a result, although there is an average annual rainfall of about 960 millimeters (Pompeu Sobrinho 1916), only a very small amount is taken up by the soil. The rest, from the moment of its first contact with the parched hot soil to the beginning of the subsequent rainy season, is subject to constant evaporation. Of the water which rushes down the steep mountainous slopes of the upper reaches of the rivers, flooding the wide shallow river beds and overflowing the banks, only a small amount ever reaches the sea. In the Jaguaribe, largest river system of the region, Pompeu Sobrinho calculated that of an average rainfall of 68,760 million cubic meters during the years 1912-14, 4 per cent was taken up by the soil, 6.5 per cent was drained off to the sea, and almost 90 per cent was lost by evaporation.

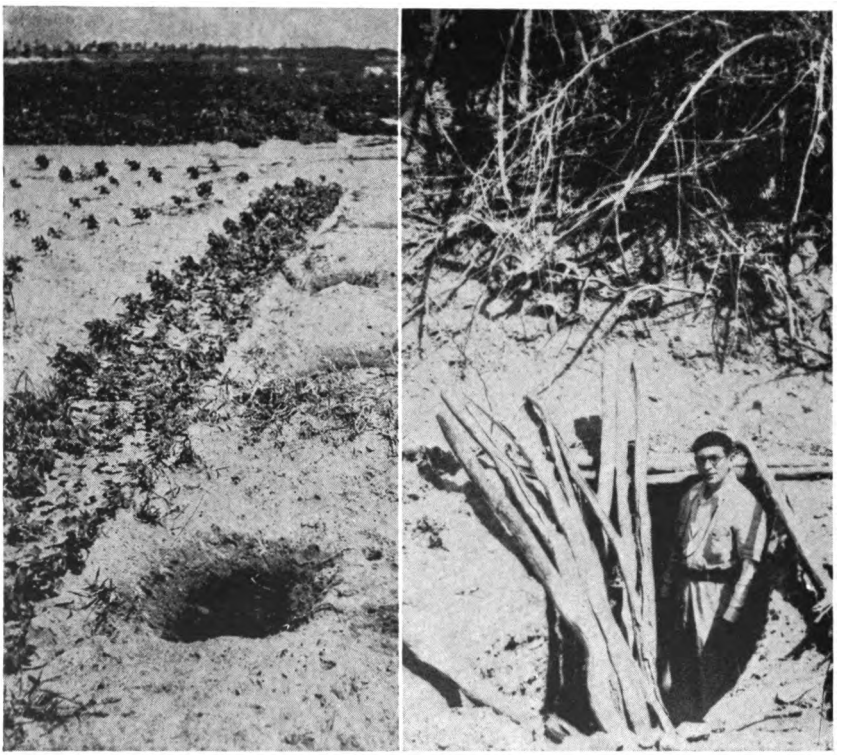
In general, therefore, it can be said that the valleys of the rivers of this region are separated from each other by high dry plateaus or mountain ranges. Even the rivers of the coastal plain, which are short and parallel each other in a more or less direct course to the sea, are generally separated from each other by sandy or dry elevated areas, offering few opportunities for the formation of ground pools suitable for mosquito production.

Areas Suitable to Gambiae

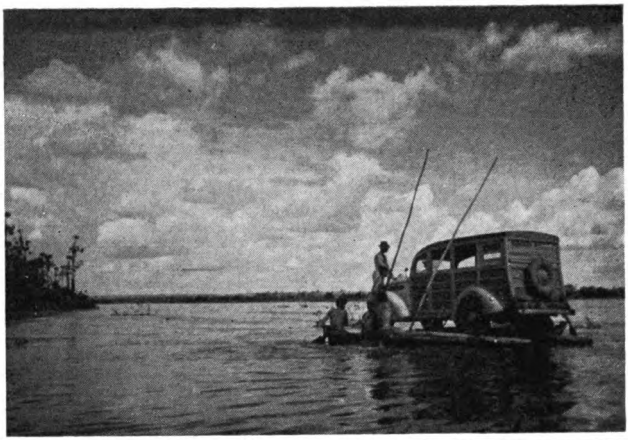
It is in the lower valleys of the larger rivers (the Assú and the Apodí, in Rio Grande do Norte, and the Jaguaribe with its tributaries, in Ceará) that the best conditions for gambiae production obtain, the degree of suitability varying directly with the size of the river. Thus, the Potengí and the Ceará Mirím valleys, the first to be invaded by gambiae, are not nearly so propitious for its development as are those of the Assú and Apodí, which again are not so favorable as is the Jaguaribe valley with its vast ramifications of tributaries. This may be explained by the amount of water available in these areas and their suitability for human settlement. The river beds themselves, with their rich alluvial

deposits and their subsurface water sheet, offer almost the only opportunity for agricultural production during the dry season (Figs. 4, 5), and because of their high water table, the alluvial plains bordering the rivers are the native habitat of the carnauba palm (*Copernicia cerifera*), the extraction of whose wax is one of the chief industries of the lower river valleys. Large stretches of these plains are to be found along the Assú, Apodí, and Jaguaribe rivers.

The peculiar system of agriculture of the region is an adaptation to these conditions. During the flood season crops cannot be planted on the lowlands because of inundations, but after the surface has dried there remains for many weeks a sufficiently high subsurface water table to permit the growing of crops in



FIGS. 9 and 10.—Other views of caçimbas. Note depth of well at right.



FIGS. 11 and 12.—The Jaguaribe and Banabuiú rivers in rainy season.

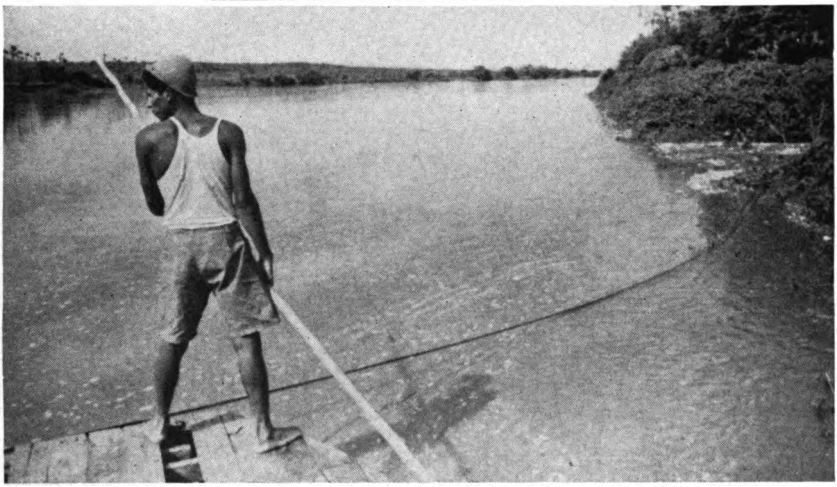


FIG. 13.—River bed in dry season.

FIG. 14.—Dry sandy river course.

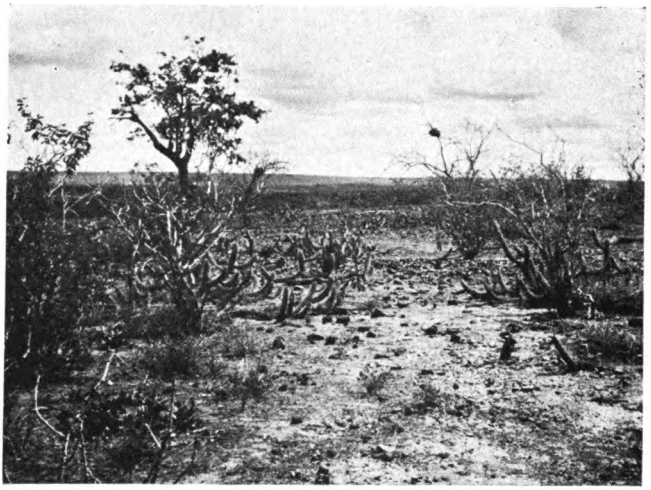


FIG. 15.—View of countryside in long dry season.

FIG. 16.—Carnauba flats in the wet season. The clay soil absorbs little rain.

the dry river bed. An essential part of this system of agriculture is the digging of shallow wells or ditches in the sand from which water can be scooped up for watering the growing crops. These wells, known as "caçimbas de aguação" (Figs. 6-10), are small shallow pools generally completely exposed to the tropical sun and are greatly preferred by the gambiae mosquito. They have been an important factor in the dry season maintenance of the species in certain areas. During the wet season, the river beds are flooded and unsuitable for the production of gambiae, but at this period there are myriads of small shallow sunlit pools everywhere in the surrounding country, for water permeates the clay soil of the alluvial plains very slowly. With the onset of the dry season, most of these marginal or extra river-bed breeding areas disappear, but by that time the formation of both natural and artificial pools (caçimbas) has made the river bed itself attractive. Thus the year-round cycle of breeding depends in certain areas on man-made foci.

The larger rivers in the region generally flow from three to five or six months of the year (Figs. 11, 12), but once the rains cease even they rapidly dry up and eventually are reduced to occasional stagnant pools. The long dry season transforms the countryside into a barren waste relieved by vegetation only along the river bottoms and in some parts of the mountain ranges. Nothing could be more surprising than the contrast in the appearance of the rivers and the countryside at the height of the rains and at the end of the dry season. The river, which a few months previously was a raging flood, presents the aspect of a dry sandy river course (Figs. 13, 14) interrupted only by an occasional stagnant pool, and the entire countryside which was verdant with exuberant vegetation has become a grayish picture of desolation (Fig. 15), except for the crops planted in the river bed itself and for the carnauba palms (Figs. 16, 17) which have taken possession of the alluvial plains.

Away from the alluvial plains of the lower river valleys and on the plateaus, the region is covered with a scrubby type of vegetation to which the name caátinga is given (Sampaio 1938). During the rainy season, the areas covered by caátinga are beautifully green, but become barren during the dry months when practically

all the scrub loses its leaves. Even during the rainy season, however, the thin porous soil which supports the caátinga vegetation does not permit the formation of standing pools of water suitable for the production of gambiae.

Next in importance to the river valleys are the seepage areas, suitable to permanent maintenance of gambiae breeding, which occur in both Rio Grande do Norte and Ceará. The most important of these seepage areas are to be found all along the coastal strip where the sand dunes absorb the rain water and release it slowly, as seepage, very much as might forested hills. These seepage areas are cultivated intensively throughout the year. For irrigation purposes, shallow ditches are dug (Fig. 18) into which the water seeps and remains at a fairly constant level over long periods. These, like their river-bed equivalent, the caçimbas, are especially favorable to gambiae breeding.

Seepage areas also occur in the vicinity of the mountain ranges, the Araripe presenting those most suitable for gambiae production. Here innumerable springs arise at a fairly uniform height of 675 meters, many of which are diverted or impounded for irrigation, power production, and for potable water supplies. Had

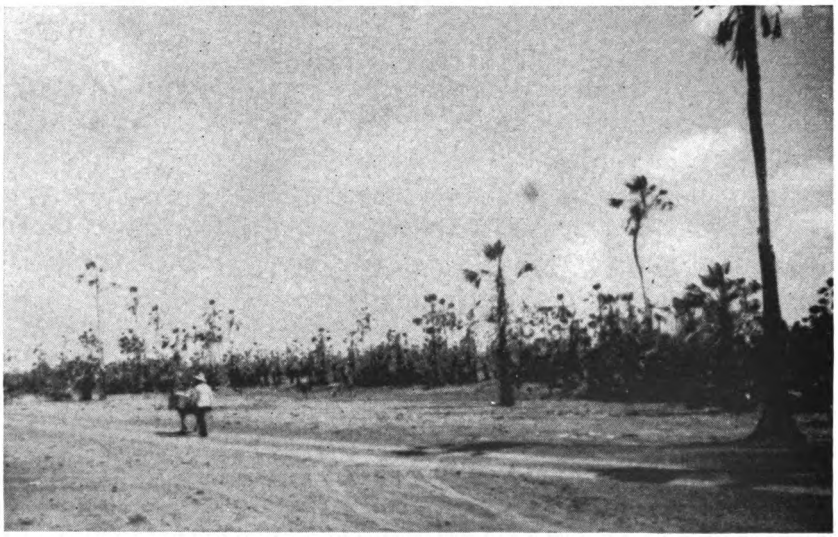


FIG. 17.—Carnauba flats in the dry season.

FIG. 18.—Sweet potato cultivation with seepage irrigation.

FIG. 19.—Lake Piató. Hoofprints make ideal gambiae breeding places.

gambiae reached this section, it would have found another area with conditions favorable to permanent residence. Along the Ibiapaba mountain range, very few springs appear on the Ceará side of the border, for the strata slope gently westward, carrying the subsurface water into the State of Piauí. The Apodí range, either in Ceará or Rio Grande do Norte, likewise gives rise to but few permanent springs, the best known being those near Limoeiro, in Ceará.

Another very favorable area which gambiae never reached is that along the coast to the east and west of Fortaleza, between the Choró and Curú rivers, which receives a larger and more evenly distributed rainfall than that of Rio Grande do Norte and the Jaguaribe valley and where there is an abundant supply of subterranean water which feeds permanent springs, seepages, lakes, and streams (Small 1923, publ. 25). Much of this region is low and flat, with a clay soil surface having numerous shallow depressions highly favorable to the formation of shallow sunlits pools suitable for gambiae breeding.

Lakes and reservoirs and similar large bodies of water do not of themselves offer good breeding opportunities to gambiae. But if the margins are such that with the falling water level pockets of water are left in animal hoofprints and other small depressions, they may become dangerous producers. The eastern third of Ceará has many lakes of this type, but the two largest in the entire region, Lakes Piató (Fig. 19) and Grande, are found in the Assú valley, in the State of Rio Grande do Norte.

The federal government has for many years been engaged in a reservoir-building project in both states in an effort to impound water for use during the dry season. For the most part reservoirs have been built in the rocky upper reaches of the rivers, the stony margins of which do not offer the same opportunities for gambiae breeding as do the lakes in the alluvial plains. Some seepage occurs at the base of several of these reservoirs, forming pools suitable for gambiae production.

CLIMATE OF NORTHEAST BRAZIL

Temperature

Considering the fact that this area lies close to the equator, the climate of upper Northeast Brazil is remarkably pleasant. The temperature is singularly constant and relatively low, probably because of the influence of the prevailing sea breezes during the summer months. Table 2 gives the mean daily maximum and minimum temperatures by months during 1940 and 1941 for five typical localities in the States of Rio Grande do Norte and Ceará. It will be noted that the maximum dry-bulb reading usually re-

TABLE 2

MEAN OF DAILY MAXIMUM AND MINIMUM DRY-BULB TEMPERATURES BY MONTHS, IN FIVE SELECTED LOCALITIES IN CEARÁ AND RIO GRANDE DO NORTE

1940 and 1941

MONTH	TEMPERATURE	CEARÁ				RIO GRANDE DO NORTE					
		IGUATÚ		QUIXERAMOBIM		NATAL		ASSÚ		MACAÍBA	
		1940	1941	1940	1941	1940	1941	1940	1941	1940	1941
January	Max.	33°0	34°8	33°5	34°4	30°6	29°6	31°8	34°6	31°6	33°1
	Min.	23°1	23°7	25°4	26°0	24°9	25°8	28°2	29°0	21°5	20°8
February	Max.	33°8	33°7	32°9	33°3	30°8	29°9	31°3	33°5	32°1	32°7
	Min.	23°2	23°4	25°2	25°7	25°6	25°6	27°3	28°5	22°0	21°7
March	Max.	31°4	31°2	30°4	31°4	30°8	29°2	29°7	32°9	32°0	32°1
	Min.	22°7	22°7	24°2	29°4	24°3	24°3	25°9	28°2	22°1	21°5
April	Max.	31°1	31°6	29°7	31°1	29°4	30°1	29°7	33°0	30°6	31°6
	Min.	23°0	22°7	24°2	25°1	23°1	24°6	25°0	28°4	22°4	22°1
May	Max.	29°9	31°5	28°7	31°0	28°8	29°4	26°8	33°4	29°6	30°5
	Min.	22°0	21°6	23°8	24°3	22°6	22°3	25°7	28°6	22°1	21°1
June	Max.	29°6	32°5	28°1	32°1	28°0	28°5	30°6	33°4	28°9	29°6
	Min.	20°1	21°2	22°4	24°4	21°7	22°1	24°7	28°7	20°7	20°4
July	Max.	30°7	32°7	29°7	31°7	27°6	27°8	31°1	33°6	28°5	28°6
	Min.	20°1	20°8	22°3	23°7	21°0	21°7	24°4	28°5	20°0	19°8
August	Max.	33°3	33°4	32°0	32°9	28°0	27°7	31°2	33°5	28°7	29°0
	Min.	20°7	21°5	23°3	24°3	21°4	21°6	27°6	28°3	19°7	19°5
September	Max.	34°8	35°6	33°6	33°6	29°2	28°3	31°5	33°7	30°2	30°6
	Min.	22°2	21°9	24°4	24°4	22°7	23°8	22°7	28°3	20°2	19°4
October	Max.	35°8	36°5	34°2	34°3	28°6	28°7	31°1	32°4	31°8	31°6
	Min.	22°4	23°0	24°7	25°0	24°3	24°2	21°5	28°4	18°2	19°9
November	Max.	35°9	35°8	34°3	34°1	28°7	28°8	33°3	33°3	32°1	31°9
	Min.	22°7	23°8	24°9	25°2	25°1	24°6	28°4	28°2	18°7	20°3
December	Max.	36°5	37°3	34°7	34°7	29°2	29°1	33°7	34°0	32°1	32°4
	Min.	24°6	24°2	25°9	25°7	25°0	24°8	27°5	28°2	21°4	21°7

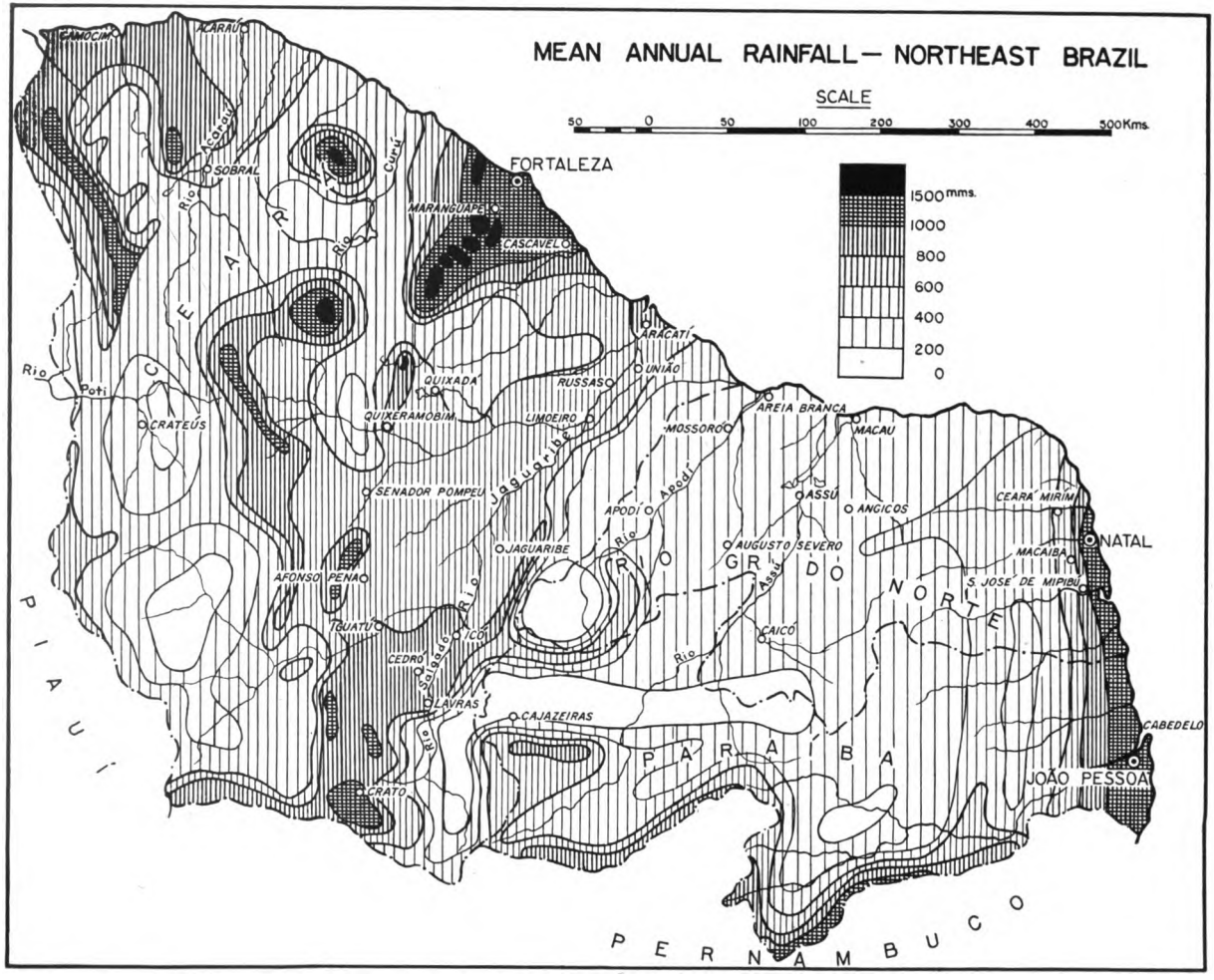


FIG. 20.

mained in the lower thirties, while the minimum seldom dropped below twenty. The minimum temperature never lasted more than a few hours a day and at no time did the temperature drop to the point where it would interfere with gambiae production.

Rainfall

Based on the pluviometric charts of Williams and Crandall (1910) and of Pereira da Costa (1942), the map opposite shows roughly the amount of annual rainfall in Northeast Brazil. It is apparent that this varies in Rio Grande do Norte from less than four hundred millimeters in the central and western two thirds of the state, to between four and eight hundred millimeters in the rest of the state, with the exception of the well-watered eastern coastal strip which receives even greater moisture from the equatorial South Atlantic air masses. The Assú and Apodí valleys in Rio Grande do Norte receive less rain than does the Jaguaribe valley, but farther down the coast, the region which includes Natal, Ceará Mirím, and Macaíba has a heavier rainfall which often lasts through the month of August.

Whereas much of the State of Ceará receives less than six hundred millimeters of rainfall, most of the region drained by the Jaguaribe has over six hundred millimeters per year and some parts of it more. Certain other definitely well-watered areas have over eight hundred millimeters of rainfall annually. These include the Fortaleza region, the upper northwestern corner of the state, the central water divide, and the Araripe range.

Relationship of Rainfall to Gambiae Production

Table 3 shows variations in rainfall, by months from 1936 through 1941, for eleven places chosen to represent typical conditions in different parts of the State of Ceará in relation to actual and threatened infestation with gambiae (Fig. 2). Aquiraz may be taken as representative of the Fortaleza zone which was seriously threatened by the appearance of gambiae at Caponga, lying only twenty-five kilometers from Aquiraz, and Cascavel, where the total rainfall for the six-year period is only slightly lower than that in the Fortaleza zone. The other points chosen for presentation of data are distributed throughout those parts of the

TABLE 3

RAINFALL (IN MILLIMETERS), BY MONTHS, FROM 1936 TO 1941, IN DIFFERENT PARTS OF CEARÁ

LOCALITY	YEAR	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	TOTAL
Aquiraz	1936	14	115	63	69	181	60	23	9	8	2	8	1	553
	1937	6	282	138	273	245	183	45	19	32	8	24	77	1,332
	1938	94	53	331	582	90	95	35	18	12	16	49	15	1,390
	1939	56	550	354	209	258	17	57	4	42	17	54	8	1,626
	1940	176	170	245	324	246	145	30	9	29	16	*	49	1,439
	1941	*	85	281	294	75	23	7	14	8	3	20	41	851
Cascavel	1936	25	157	52	64	153	56	8	*	3	8	11	*	537
	1937	5	323	222	412	286	152	5	14	23	*	9	69	1,520
	1938	101	93	379	546	69	91	*	*	*	2	14	14	1,309
	1939	47	650	277	103	70	*	85	*	28	55	54	18	1,387
	1940	119	118	148	339	318	33	4	*	11	*	5	37	1,132
	1941	*	94	222	109	18	*	5	*	59	7	8	41	563
Aracatí	1936	13	168	15	44	29	91	8	*	*	3	*	*	371
	1937	*	308	136	394	374	139	16	6	*	4	8	12	1,397
	1938	40	13	418	271	95	22	1	5	*	*	*	*	865
	1939	40	322	247	89	24	31	15	17	*	57	20	16	878
	1940	87	101	234	421	261	98	45	3	4	*	*	16	1,270
	1941	34	142	238	93	21	4	*	*	*	3	8	82	625
União	1936	27	222	55	16	47	111	13	*	*	*	*	5	496
	1937	*	219	93	155	194	59	18	*	*	*	*	*	738
	1938	30	45	382	232	70	5	*	*	5	*	5	*	774
	1939	4	276	193	71	24	*	11	8	*	17	*	*	604
	1940	54	87	110	319	189	73	92	8	*	*	*	*	932
	1941	2	67	78	64	4	10	*	*	*	*	6	*	231
Limoeiro	1936	52	290	62	32	22	163	4	*	*	*	*	*	625
	1937	6	158	156	164	104	92	4	*	*	4	*	7	695
	1938	76	4	246	148	67	40	*	*	*	1	3	*	585
	1939	3	216	171	86	20	13	11	14	*	26	6	15	581
	1940	132	101	426	243	155	60	17	10	*	*	*	4	1,148
	1941	16	118	231	140	69	6	4	*	*	*	*	6	590

Bara do Sitiá	1936	10	222	61	15	43	126	4	*	*	*	*	*	481
	1937	8	173	131	102	180	24	11	*	*	*	*	18	647
	1938	56	15	446	199	88	10	3	*	*	*	*	*	817
	1939	5	109	66	99	14	18	9	26	3	*	11	2	362
	1940	54	111	304	245	263	78	43	*	*	*	*	*	1,098
	1941	4	71	172	118	21	13	21	*	*	*	*	2	422
Poço do Mato	1936	106	339	188	241	*	48	*	*	*	7	*	12	941
	1937	20	235	173	163	91	21	5	*	5	*	*	16	729
	1938	172	15	432	147	15	*	8	*	59	*	*	*	848
	1939	12	320	211	135	138	18	*	6	18	32	40	98	1,028
	1940	119	161	356	211	66	0	66	8	27	14	*	35	1,063
	1941	93	84	227	139	66	*	*	26	*	14	32	*	681
Açude Lima Campos	1936	78	174	172	72	125	†	†	†	†	1	†	†	622
	1937	*	208	78	158	64	53	6	*	7	*	*	6	580
	1938	47	8	263	197	16	13	*	*	*	10	*	*	554
	1939	26	200	176	36	83	32	50	29	8	138	50	35	863
	1940	22	0	420	202	595	71	2	2	0	12	0	0	1,326
	1941	56	134	244	100	41	6	8	6	0	18	9	0	622
Quixeramobim	1936	26	177	253	86	304	151	39	0	*	0	1	4	1,041
	1937	3	157	69	152	186	63	42	12	*	0	2	2	688
	1938	34	12	397	226	55	72	10	0	*	0	1	12	819
	1939	4	136	208	152	92	43	23	1	11	19	16	3	708
	1940	65	82	222	316	213	77	21	23	5	3	2	0	1,029
	1941	6	77	145	127	54	14	58	11	*	0	1	1	494
Senador Pompeu	1936	24	174	46	78	190	140	5	3	*	*	*	3	663
	1937	43	147	22	137	81	57	25	17	*	0	0	5	534
	1938	52	19	302	68	43	6	0	*	1	*	2	0	493
	1939	15	137	235	57	75	7	35	11	19	12	14	4	621
	1940	70	107	354	246	231	62	19	14	23	0	*	*	1,126
	1941	10	74	171	120	30	38	13	5	0	0	4	1	466
Crato	1936	61	272	54	166	37	16	*	*	*	*	14	78	698
	1937	133	252	194	144	63	*	*	*	2	5	70	108	971
	1938	258	46	425	115	37	12	1	*	*	10	3	16	923
	1939	*	313	232	70	35	0	51	1	*	12	180	72	966
	1940	220	253	631	166	129	3	3	*	1	10	146	64	1,626
	1941	76	182	516	176	89	*	5	0	*	0	79	23	1,146

* No rains.
† No observation made.

FIG. 21.—Pool formed by rain water.

Jaguaribe valley infested with gambiae, with the single exception of Crato which lies in the well-watered region close to the Araripe mountains, invasion of which would have created another expensive problem for the Malaria Service of the Northeast.

In considering the rainfall data for different places in Ceará it must be borne in mind that they fail to reveal the amount of water available for gambiae breeding at any one place or time,

FIG. 22.—Borrow pit refilled by each rain.

for in the upper reaches of the rivers the water drains quickly to the alluvial plains of the lower river valleys. União, for instance, near the mouth of the Jaguaribe River, had a rainfall in 1939 of only 604 millimeters, but was nevertheless one of the wettest places in the valley, as it received flood waters from all the southeastern section of the state. União continued to afford good breeding places for gambiae weeks later than Poço do Mato, for instance, on the upper Jaguaribe, with a rainfall of 1,028 millimeters in the same year. As a consequence, at the end of the rainy season, the alluvial plains of the lower valleys, even though they receive less rainfall than the upper valleys, are far more suitable for gambiae production.

The total amount of rainfall during a year is not so important as is its seasonal distribution in determining the production of gambiae. While it is true that there are definite wet and dry seasons in upper Northeast Brazil, it must be remembered that even in the dry season local showers often occur which replenish small pools (Figs. 21, 22), form new puddles on the clay soil of the alluvial plains, and increase overnight the potential breeding places of this mosquito. In a fortnight the smaller collections of water may evaporate, but in the meantime an opportunity has been given for the production of a new generation of gambiae. In the same way a limited rainfall, evenly distributed during the rainy season, may be more favorable than is a heavier rainfall coming in occasional irregular torrents. The heavy rains of the wet season are not entirely favorable to gambiae, for the beating rains, the torrents in the upper reaches of the rivers, and the floods in the lower river valleys wash away many of the gambiae foci, destroying eggs, larvae, and pupae.

The amount of rainfall in the dry season, as can be seen in Tables 3 and 4, is very much less than in the rainy season, but the dry season showers are of great importance in the production of suitable breeding places for gambiae at the most critical season.

During the months from February through May, roughly 80 per cent of the year's total rainfall occurs, whereas from August through November, generally the four driest months, only in exceptional years does the rainfall exceed 2 per cent. Such was the

TABLE 4

COMPARISON OF WET AND DRY SEASON RAINFALL (IN MILLIMETERS) IN TWENTY-FOUR* SCATTERED LOCALITIES IN CEARÁ

YEARS	YEARLY TOTAL	FEBRUARY, MARCH, APRIL, MAY	PERCENTAGE	AUGUST, SEPTEMBER, OCTOBER, NOVEMBER	PERCENTAGE
1936	14,337	11,266	78.5	87	0.6
1937	18,969	15,868	83.6	501	2.6
1938	18,434	15,602	84.6	350	1.8
1939	19,396	15,390	79.3	1,944	10.0
1940	26,855	21,480	79.9	578	2.2
1941	12,198	10,716	87.8	425	3.4

* Includes eleven localities of Table 3.

first year (1939) of the Malaria Service of the Northeast's attempt to eradicate gambiae, 10 per cent of the year's total rainfall having occurred during the four dry months, while the second year (1940) was one of the years of greatest rainfall, with 40 per cent more water falling during the rainy season than in 1939. Considering the way in which the campaign against gambiae developed, the rainfall of the years 1939 and 1940 proved most unfavorable to the campaign (Table 5). Further information on the rainfall in the States of Rio Grande do Norte and Ceará may be found in Tables 6 and 8.

Winds

Weather conditions in the section of Northeast Brazil now under discussion are subject mainly to the interaction of the air masses originating (1) in the South Atlantic, coming from a southeasterly direction, (2) in the North Atlantic Ocean, coming from a northeasterly direction, and (3) in the Amazon basin (James 1939). Between the first two lies the intertropical frontal zone which corresponds to the classic doldrums belt over the oceans. Both air masses are characterized by towering cumulus clouds and showery weather; but, whereas the equatorial South Atlantic air masses never reach the interior, touching only the coastal zone of Northeast Brazil, the equatorial North Atlantic air masses, during the southern summer, penetrate far southward into the

TABLE 5

RAINFALL, BY MONTHS, 1939 AND 1940

Ceará and Rio Grande do Norte

LOCALITY	YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	TOTAL
Aracatí	1939	40	322	247	89	24	31	15	17	—	57	20	16	878
	1940	87	101	234	421	261	98	45	3	4	—	—	16	1,270
União	1939	4	276	193	71	24	—	11	8	—	17	—	—	604
	1940	54	87	110	319	189	73	92	8	—	—	—	—	932
Morada Nova	1939	22	120	179	39	20	27	7	14	—	28	10	—	466
	1940	103	23	330	387	255	80	15	—	—	—	—	—	1,193
Quixeramobim	1939	4	136	208	152	92	44	23	1	11	19	15	3	708
	1940	65	82	222	316	213	77	21	23	5	3	2	0	1,029
Jaguaribe	1939	5	116	234	141	23	5	6	3	19	6	—	—	558
	1940	143	148	304	131	223	28	17	18	—	—	—	—	1,012
Icó	1939	59	149	197	49	76	33	18	25	7	64	44	23	744
	1940	96	181	533	133	119	25	12	—	0	—	—	—	1,099
Iguatú	1939	56	319	199	73	109	86	33	53	—	47	—	—	975
	1940	96	145	345	205	171	22	2	9	27	12	—	—	1,034
Quixadá	1939	44	237	223	130	30	22	10	7	3	13	9	9	737
	1940	120	91	302	185	237	73	65	—	—	—	—	—	1,073
Senador Pompeu	1939	15	137	235	57	75	7	35	11	19	12	14	4	621
	1940	70	107	354	246	231	62	19	—	23	0	—	—	1,112
Natal	1939	10	164	207	201	178	97	344	254	65	84	48	7	1,659
	1940	53	115	152	515	570	342	273	185	45	12	0	53	2,315
Ceará Mirím	1939	9	115	134	99	150	70	283	226	67	36	42	3	1,234
	1940	48	184	173	364	456	322	116	121	116	3	2	21	1,926
Macaíba	1939	15	239	170	162	112	72	265	168	45	40	38	9	1,335
	1940	75	127	150	274	461	257	121	110	48	8	2	61	1,694
Mossoró	1939	10	104	166	165	33	53	21	43	—	5	30	13	643
	1940	78	99	209	343	110	29	26	21	3	1	—	8	927
Areia Branca	1939	2	116	168	44	12	21	11	26	1	8	13	8	430
	1940	—	108	540	308	106	48	—	10	—	—	—	—	1,120
Assú	1939	—	87	167	186	23	8	41	38	—	12	21	3	586
	1940	27	78	226	291	140	38	30	—	—	—	—	—	830

FIG. 23.—Typical simple rural home.

heart of the continent, becoming confused with the tropical continental air masses as they cross the Amazon basin. It is this warm season indraft of moist air from the North Atlantic which produces the rainy season from December to May throughout northern and central Brazil. It extends, however, only as far south as the intertropical frontal zone, whose position at its maximum southern advance during the southern summer varies from year to year. When it moves well into the State of Ceará, the Northeast enjoys a rainy year, but when it fails to reach the borders of this state, the Northeast has one of its periodic droughts. This is common knowledge in the area, for local weathermen state that when the northeast trade winds overpower the southeast trade winds, a rainy season can be expected, while a drought is probable if the reverse occurs.

During the dry season, the sea breeze plays an important role in tempering the great heat. As the earth becomes heated during the day, a cyclonal area is established and the wind sweeps in from the sea, ascending far up the river valleys. In the Jaguaribe valley a particularly strong sea breeze, locally known as "the Aracatí" starts from the mouth of the river in the early afternoon and, ascending the valley, arrives at each village with daily regularity—Icó, for example, two hundred miles inland, at 9 P.M.

RELATIVE HUMIDITY

Unfortunately, few data are recorded as to relative humidity in the States of Ceará and Rio Grande do Norte. The whole re-

gion, however, falls within the zone of less than 80 per cent humidity and certain sections have a relative humidity as low as 65. The evaporation of excess moisture is very rapid during the dry season with its constant winds and almost cloudless skies.

Adaptation of Housing to Climate

In keeping with the climate of Northeast Brazil, the majority of the houses are so constructed that some of the rooms are dark, offering a satisfying relief from the bright sunlight which prevails throughout so much of the year. Almost all the houses, both in the smaller towns and in the rural districts, are of the one-story unceiled type. Dwellings vary from thatch-roofed cottages with open stake and wattle sides to brick houses with tile roofs (Figs. 23, 24). All have but few windows and these are closed practically always by solid wooden shutters, which keep the houses, though gloomy, much cooler than the temperature outside. Gambiae's habit of frequenting human habitations, led it to the most favorable surroundings for its preservation in a region which has a very desiccating climate during the dry season and which has no stables for sheltering animals nor natural caves which could be used as alternate refuges.

Fig. 24.—Better type of rural residence.

EARLY RESULTS OF GAMBIAE INVASION

AT THE BRIDGEHEAD, NATAL

When gambiae breeding in Natal was first detected on March 23, 1930, it was limited to a very small area and no outcry regarding epidemic malaria in the city had as yet been raised. But when one of us (F.L.S.) visited Natal some five weeks later on a tour of inspection of the antilarval work of the Yellow Fever Service on April 28 he learned from the Director of the State Health Service that malaria had unexpectedly become a most serious problem in the city.

The laboratory records of positive blood smears, January 0. February 5, March 84, first half April 110, indicated an explosive outbreak which must have been under way when gambiae was discovered. This was confirmed by personal observation when, in checking the work of the anti-aegypti service, forty houses were visited in almost every one of which one or more persons were found to be ill. Everyone in the neighborhood agreed that most families had suffered an attack rate of 100 per cent during the previous weeks.

In the absence of control measures the epidemic continued unabated during the month of May and such a large percentage of the population of the workers' suburb, Alecrim, was affected that it was necessary for the public health authorities to supply food as well as medicine to the victims and their families. The unusual number of deaths from malaria gave rise to the rumor that yellow fever had once more appeared in the city after an absence of several years. The late Dr. N. C. Davis, director of the yellow fever laboratory in Baía, visited Natal during the last week in May and confirmed the observation that the attack rate in the district along the river bank, where gambiae was originally found, and on the bluff above was almost 100 per cent. At that time (May 27) gambiae was found to have extended its range of breeding about one kilometer beyond the area of infestation observed in March. Dissection of gambiae collected in houses in the epidemic zone showed a truly astounding rate of infection. Davis found 52, or 30.2 per cent, glands with sporozoites and 108, or 62.8 per cent,

midguts with oocysts, in 172 dissections. Thirteen of the 102 infected midguts had more than 100 oocysts each, one stomach had some 600 oocysts, and another 400. It was not unusual to find two well-differentiated sets of oocysts in the same mosquito. Since the mosquitoes were dissected as soon as their blood meal was digested, undeveloped infections may have been missed (Davis 1931).

At the end of June malaria still continued to be a serious problem although some Paris green was being used on the riverside foci. During the following months of the dry season, the situation became quiescent and continued thus until the end of the year.

In December 1930 gambiae was found (Shannon 1932) to have extended its breeding range at Natal to an area roughly estimated at six square kilometers. In keeping with this local extension of breeding range, the second gambiae-borne epidemic of malaria in Natal, which began in January 1931, was far more serious than the first: some 10,000 cases are reported to have occurred in a population of 12,000 people in Alecrim, the workers' suburb. The Light and Power Company, the Naval Academy, and even the Yellow Fever Service itself found difficulty in maintaining their routine activities because a large part of their staffs was ill during this epidemic.

Within a few weeks' time the epidemic became so severe that the state authorities appealed to the federal government for aid. The responsibility for immediate organization of control measures was given to the only federal health service active in the state, the Cooperative Yellow Fever Service maintained jointly by the Ministry of Education and Health and The Rockefeller Foundation. Control measures, consisting of dusting with Paris green, were begun early in March and were continued under the auspices of this Service until October 13, when Dr. Geneserico Souza Pinto became director of the State Health Service of Rio Grande do Norte especially to direct measures against gambiae, for which the federal government appropriated three hundred contos (about $20,000 U.S. in 1931).

During the four weeks preceding October 13, the date on which the responsibility for gambiae control passed from the Yellow

Fever Service to the State Health Department, only five adult gambiae were found in house captures in Natal in comparison with over four hundred found during the first four weeks of March. The State Health Department continued the work in Natal and when measures against gambiae were abandoned in April 1932 was able to announce that there were no more gambiae in that city (Souza Pinto 1932). From that time on, even during the hectic years 1938 and 1939 when gambiae was plentiful at nearby Igapó, it was never again found in the city itself.

Although it is true that 1932 was a year of drought in Northeast Brazil, the rainfall of the area about Natal that year (Table 6) would have been adequate to maintain gambiae in the absence of control measures, and there seems to be no reason for not attributing the disappearance of gambiae from Natal to the campaign carried out in 1931 and early in 1932.

An analysis of the mortality statistics of Natal gives a clear picture of the rise in deaths from malaria during 1930 and 1931 and the return to a more normal level after the antigambiae campaign (Table 7).

The increase in the number of deaths caused by malaria in postgambiae over pregambiae years can be attributed in part to fatalities from gambiae-transmitted malaria among out-of-town patients brought to Natal for treatment. The increase in total

TABLE 6

RAINFALL (IN MILLIMETERS), BY YEARS, RIO GRANDE DO NORTE

1932 to 1941

YEARS	NATAL	CEARÁ MIRÍM	MACAÍBA	MOSSORÓ	AREIA BRANCA	ASSÚ
1932	1,239	814	961	232	194	302
1933	1,288	972	797	424	617	428
1934	1,620	1,105	1,059	895	1,098	596
1935	2,079	1,602	1,570	1,110	1,603	1,085
1936	1,513	1,188	954	362	357	218
1937	1,700	977	880	464	875	543
1938	1,517	954	811	837	474	470
1939	1,659	1,234	1,335	643	430	586
1940	2,315	1,926	1,694	927	1,120	830
1941	1,150	887	1,015	245	365	146

TABLE 7

MORTALITY STATISTICS OF NATAL

1925 to 1940

YEAR	POPULATION (YELLOW FEVER SERVICE FIGURES)	TOTAL DEATHS (ANNUAL)	DEATHS BY MALARIA (ANNUAL)
1925	—	857	23
1926	—	946	10
1927	—	1,154	13
1928	—	998	24
1929	—	1,014	28
1930	—	904	139
1931	—	1,429	344
1932	37,015	1,279	96
1933	38,119	1,058	40
1934	—	1,172	43
1935	—	939*	31*
1936	42,299	1,424	59
1937	—	1,394	50
1938	48,568	1,392	70
1939	50,081	1,497	41
1940	50,192	1,579	37

* Only 9 months; archives of 4 months destroyed by fire.

annual deaths during recent years can be attributed at least in part to the growth in the population of the city, as can be seen from the Yellow Fever Service figures of 37,015 for 1932 and 50,192 for 1940.

EXTENSION TO THE INTERIOR

In December 1930, at the very end of the dry season, a survey of Natal and the surrounding region was made (Shannon 1932) to determine whether gambiae had advanced farther from the site of original invasion. Many localities along the coast, both north and south of Natal, and in the interior of the state were visited without finding any evidence of gambiae away from Natal itself.

The report of this survey makes interesting reading in the light of following events:

I would therefore venture to state that the coast and the interior of the states of Pernambuco north to Maranhão are for by far their greater part an impossible breeding ground; that the problem of controlling this species in this

territory (even though the species become widely established) will always be extremely local, i.e., confined directly to the immediate environs of the city (Shannon to Davis. Letter, December 18, 1930).

Shortly after the Yellow Fever Service began control measures in Natal, it became apparent that gambiae was no longer limited to the immediate environs of that city. In the last weeks of April 1931 rumors of serious outbreaks of malaria at various points lying in the river valleys just northwest of Natal were rife. Field investigations were not made of these points immediately, but subsequently it was shown that the districts about São Gonçalo, Macaíba, Ceará Mirím, and Taipú, were heavily infested. Although malaria is endemic in the Potengí and Ceará Mirím valleys, the gambiae-transmitted epidemic of 1931 was so extraordinary that both São Gonçalo and Ceará Mirím were almost depopulated by the wholesale emigration of those able to flee. As many as ten deaths daily are said to have occurred in Taipú in a population of some six thousand people. Dissections of 397 female gambaie from São Gonçalo and Taipú showed mosquito infections paralleling those registered for Natal the previous year: 112, or 28.2 per cent, glands with sporozoites; 284, or 71.5 per cent, midguts with oocysts (Souza Pinto 1938).

A rapid survey of gambiae breeding made early in September 1931 showed the presence of gambiae in the following localities: at Varzea de Dentro, Capela, Itapassaroca, Gravatá, and Engenho do Vale, in the county of Ceará Mirím; at Taipú, Gameleira, Poço Branco, Bôa Vista, Serra Pelada, and Pitombeiras, in the county of Taipú; and in the entire region along the river bank, in the county of Baixa Verde.

In the meantime, however, gambiae had been found during June at two points on the coast north and west of Natal, where the occurrence of unusual outbreaks of malaria called attention to its presence. The first of these points to be investigated, Redinha, is a small fishing village only a couple of kilometers from Natal and the finding of gambiae here can be explained on the basis of flight of adults in the direction of the prevailing winds. The explanation of the finding of gambiae at São Bento, a small village of 1,200 people on the coast 182 kilometers northwest of Natal, is not so evident; transportation by boat along the coast or by auto-

mobile from the intermediate infested points already mentioned, would seem to be the most likely hypothesis. The result of gambiae's arrival at São Bento was forty deaths from malaria in less than two months' time.

The fact that gambiae was early eliminated from Natal undoubtedly influenced its failure to spread to the southern coastal plain and other points linked by various systems of transportation to that capital. It must be remembered that the interior points, infested with gambiae during 1931 before Natal was cleaned, are naturally much less suitable than Natal as dissemination centers.

FAILURE TO ERADICATE GAMBIAE DURING ITS EARLY YEARS IN BRAZIL

At the time of its discovery in Brazil, the breeding of gambiae was apparently limited to a small strip along the river bank where intensive anopheline production was possible only on the previously harmless tidal flats which had been transformed by dikes into fresh-water hayfields. The greater part of this early production of gambiae could have been eliminated, and with it all possibility of the severe local outbreaks of 1930 and 1931, simply by opening the dikes and permitting the free entry of tidal water. The recommendation that this be done was made to the proper authorities in May and September, 1930, and subsequently at frequent intervals during the next twelve months. That it was done only after the regional disaster of 1938 was due entirely to the fact that local health officers did not have the necessary authority to overcome the power of vested interests.

The possibility of species eradication of gambiae was discussed with the federal health authorities in June and again in September, 1930, but nothing was attempted; the memory of the yellow fever outbreaks of 1928-29 in Rio de Janeiro, Brazil's beautiful capital, was still fresh and the control of that disease took priority over all other health problems.

When early in 1931 the State of Rio Grande do Norte appealed to the federal government for aid, the question of eradication was again discussed, but the Yellow Fever Service felt unable to undertake the task since the program of expansion of yellow fever con-

trol measures was already taxing available funds and personnel to the utmost. It did, however, as described above, organize and maintain an emergency campaign to face the immediate situation in Natal until the National Department of Health had secured a trained malariologist and made financial arrangements for the organization of an eradication campaign. Before the eradication of gambiae from Natal had been accomplished, extension to the interior had already occurred. The Yellow Fever Service undertook control measures which resulted in apparent eradication from São Bento, the most distant point found infested, and the state health service organized measures at other points in the interior, with the result that in April 1932, at the same time that eradication of gambiae from Natal was published, it was announced that there were very few gambiae in the interior of the state.

The elimination of gambiae from Natal might under other circumstances have stimulated the organization of a persistent effort to eradicate this mosquito from the country, but the cessation of outcries from the state capital and the record drought which set in, with its multiple problems of famine and disease, caused the authorities to concentrate all their attention on other matters. The fact that the mosquito persisted in the interior of the state, where it undoubtedly continued to cause much malaria in districts previously malarious, aroused little interest once the state capital had been pronounced clean of gambiae.

The year 1932 was one of drought and, to make bad matters worse, followed two years of less than normal rainfall. Records for Ceará show that the rainfall in 1932 was greater than that in 1919 (Table 8), the last previous drought year, yet the resulting calamity was far worse because of the cumulative effect of three years of reduced moisture. The seasonal lack of rain is a matter of routine in the life of the Northeast, all the habits and customs of the people being adjusted to it, but failure of the rains during the rainy season of any year constitutes a major tragedy. Then, one by one, all the sources of water which persist during an ordinary dry season begin to dry up and a tide of migration sets in, drought refugees going as far south as the coffee plantations of São Paulo and as far north and west as the rubber-producing lands of Amazonas and Acre. The majority, of course, live in misery

as near home as possible through the famine and pestilence which always accompany drought, the survivors returning to their homes as soon as reports of the first rains reach them.

In 1932 the attention of both state and federal authorities became absorbed entirely with the problem of the drought victims and the consequent famine. The federal government established working camps to accommodate the refugees from the drought-stricken areas, the first of which began to function as early as April in Ceará, others being opened in Rio Grande do Norte and Paraíba in July. At one time 512,830 persons were re-

TABLE 8

RAINFALL (IN MILLIMETERS), BY YEARS, CEARÁ

1913 to 1941

YEARS	ARACATÍ	UNIÃO	MORADA NOVA	QUIXERAMOBIM	JAGUARIBE MIRÍM	ICÓ	IGUATÚ	QUIXADÁ	SENADOR POMPEU
1913	1,132	618	952	970	754	764	1,012	1,182	1,284
1914	443	901	976	910	864	864	832	1,045	1,246
1915	112	161	236	209	119	265	271	203	224
1916	657	641	661	875	727	1,000	856	1,008	627
1917	1,428	1,302	1,314	1,451	1,201	1,259	1,207	1,423	1,178
1918	1,077	843	679	646	673	1,078	973	858	1,026
1919	193	165	147	262	182	166	254	210	63
1920	975	918	681	721	788	852	824	734	506
1921	1,583	1,123	1,066	992	977	940	1,268	1,347	813
1922	1,195	904	1,117	1,283	918	1,007	839	1,059	977
1923	778	568	623	566	624	807	833	692	687
1924	1,703	996	1,630	1,350	1,246	1,119	1,058	1,875	1,600
1925	585	367	840	881	848	—	—	1,026	809
1926	935	630	704	769	597	—	—	900	746
1927	750	617	620	801	626	—	593	669	612
1928	914	640	594	568	518	—	524	585	—
1929	1,239	866	1,304	765	927	—	744	859	688
1930	569	332	306	401	439	507	653	445	733
1931	579	531	707	521	406	502	474	526	315
1932	239	175	347	294	287	363	416	286	280
1933	850	778	704	649	702	831	484	734	640
1934	1,120	1,079	964	1,242	981	1,001	1,112	1,012	1,010
1935	1,446	1,170	1,420	896	963	689	714	778	897
1936	371	496	501	1,022	508	655	623	799	663
1937	1,397	738	753	688	668	618	569	678	534
1938	865	770	874	613	619	541	621	749	493
1939	878	604	467	708	558	744	975	737	621
1940	1,270	932	1,193	1,030	1,012	1,099	1,034	1,073	1,112
1941	625	231	260	494	382	—	534	—	466

ceiving government aid in twenty-two different camps in Ceará alone and 46,425 men were on work relief in Rio Grande do Norte and Paraíba.

The condition of a destitute population in emergency camps which in most cases entirely lacked piped water supplies and adequate provision for waste disposal, could not fail to create serious health problems. Under such conditions it was only natural that the attack on the quiescent gambiae was sacrificed in the interests of more urgent programs.

Only in 1938, after the invasion of the valleys of the Assú and Apodí rivers in Rio Grande do Norte, and of the Jaguaribe River in Ceará, with the resulting epidemics of malaria in these generally nonmalarious valleys, was attention called once more to the importance of gambiae in the production of malaria in the Potengí and Ceará Mirím valleys, where it must have continued to exist throughout the intervening years. An increase of malaria in a known malarious region never causes the same outcry as does an outbreak in virgin territory.

THE SILENT ERA—1932 TO 1937

The five years from 1932 to 1937 may be referred to as the silent period in the history of gambiae in Brazil. During that time gambiae did not make itself conspicuous and no serious outbreaks of malaria are known to have occurred. But this apparently inactive interim was most significant since gambiae was spreading to more favorable regions.

Following its elimination from Natal and the subsequent suspension of the antigambiae work in April of 1932, gambiae dropped into obscurity. It was not recorded for any place in Brazil during the last eight months of 1932 and was reported for only three points in the Potengí valley during 1933 where it was found by the Yellow Fever Service on its routine investigations of aegypti distribution. However, in March 1934 the Yellow Fever Service made a special study of the distribution of gambiae which showed that the species had weathered the 1932 drought success-

fully and was still present in the Potengí and Ceará Mirím river valleys, as well as at points along the coast (Table 9). The fact that gambiae was still present in Brazil was duly communicated at the Ninth Pan American Sanitary Conference, in November 1934 (Soper).

The data in Table 9 fail to give the picture of gambiae's spread, since the Yellow Fever Service suspended further special investigations of gambiae to devote its attention to the many problems relating to the study of the newly discovered (1932) jungle yellow fever which spread over South Brazil in a remarkable series of wave-like epidemics from 1934 to 1940 (Soper 1938). No record exists of gambiae in Brazil during 1936, although during 1935 routine investigations of the distribution of *Aedes aegypti* revealed gambiae in the same area reported for 1934 and also at Macaíba, south and west of Natal. That gambiae was spreading along the coast, however, was shown by the capture of this species by the Yellow Fever Service in 1937 at Barreiras, about one hundred kilometers from São Bento, the nearest point previously reported infested, and at Macau at the mouth of the Assú River, twenty-four kilometers southwest of Barreiras. It was also caught at Taipú in the Ceará Mirím valley during 1937. However, even though gambiae took advantage of the silent period to spread, certain events occurred during those same years which were later to exert great influence in the struggle against the invader: Contact was established in Africa with workers familiar with gambiae, and the Yellow Fever Service in Brazil worked out methods for the eradication of *A. aegypti* which were later adapted to the campaign directed against *Anopheles gambiae*.

In 1935 the senior author had an opportunity to visit the gambiae-infested districts of Natal, South Africa, in company with Dr. G. A. Park Ross who had demonstrated the high susceptibility of *A. gambiae* imagoes to spray insecticides (1936). During the following weeks contacts were established with workers in Kenya, Uganda, and the Anglo-Egyptian Sudan who were familiar with gambiae.[1] A great deal of first-hand information was thus secured

[1] Of very special value was the contact established at that time with Mr. C. B. Symes, medical entomologist, Kenya.

regarding the cardinal points of gambiae biology in its native habitat, information which proved of certain value when gambiae eradication was later attempted in Brazil.

Previous to 1930 it was customary in campaigns against *Aedes aegypti* to depend on the search for larval foci to orient anti-

TABLE 9

KNOWN DISTRIBUTION OF GAMBIAE, BY YEARS

1930 to 1937

LOCALITY	1930	1931	1932	1933	1934	1935	1936	1937
Potengí River Valley								
Natal	*	*	—	—	—	—	—	—
Praia Redinha	—	*	—	—	—	—	—	—
São Gonçalo	—	*	*	*	*	*	—	*
Utinga	—	—	—	—	*	—	—	—
Santo Antonio	—	—	—	*	*	*	—	—
Barreiros	—	—	—	—	*	*	—	—
Igapó	—	—	—	—	*	—	—	—
Rego Moleiro	—	—	—	*	*	—	—	—
Macaíba and neighboring towns	—	—	—	—	—	*	—	*
Ceará Mirím River Valley								
Taipú	—	*	—	—	—	—	—	*
Gameleira	—	*	—	—	—	—	—	—
Poço Branco	—	*	—	—	—	—	—	—
Bôa Vista	—	*	—	—	—	—	—	—
Serra Pelada	—	*	—	—	—	—	—	—
Capela	—	*	—	—	—	—	—	—
Pitombeiras	—	*	—	—	—	—	—	—
Baixa Verde	—	*	—	—	—	—	—	*
Ceará Mirím (rural)	—	*	—	—	—	—	—	—
Ceará Mirím (village)	—	—	*	—	—	—	—	*
Varzea de Dentro	—	*	—	—	—	—	—	—
Itapassaroca	—	*	—	—	—	—	—	—
Gravatá	—	*	—	—	—	—	—	—
Engenho do Vale	—	*	—	—	—	—	—	—
Extremoz	—	—	—	—	*	—	—	—
Assú River Valley								
Macau (almost on coast)	—	—	—	—	—	—	—	*
Coast								
São Bento	—	*	—	—	—	—	—	*
Touros	—	—	—	—	*	—	—	*
Bôa Sica	—	—	—	—	*	—	—	—
Barreiras (near Macau)	—	—	—	—	—	—	—	*

* Gambiae present.

mosquito measures. It was found that mosquito breeding could be brought to a very low point but that any attempt at eradication of the species was bound to fail. Toward the end of 1930 the search for adult aegypti was introduced as a check on the results of the search for larval foci. It was soon found that the search for adults is the most sensitive indicator of the presence of *A. aegypti* in an area and is invaluable in locating such hidden primary perpetuating foci as may remain after the gross infestation, revealed by the search for larvae, has been eliminated by routine measures. At about the same time effective measures were introduced to eliminate as mosquito-producing foci all water containers found with larvae, either by destruction of the containers themselves, or by oiling with a larvicidal mixture of three parts fuel oil and one part Diesel oil. The introduction of these two measures, namely, the search for adults for the localization of hidden generating foci, and the routine destruction or oiling of all foci found, was followed by the complete disappearance of *A. aegypti* breeding from an ever-increasing number of Brazilian cities, and even states, from 1932 on (Soper 1937; Soper and Wilson, 1942). Considering the fact that the eggs of *A. aegypti* may remain viable for many months, it appeared that the elimination of this species should be basically more difficult than that of a highly domestic anopheles, such as gambiae, since anopheles eggs are generally incapable of hibernation.

Even after it was apparent that *A. aegypti* could be eradicated from any given area with the technique described, final results were often disappointingly slow and it was found that success in species elimination was to be achieved only on the basis of careful organization and meticulous supervision. It is not sufficient to plan a program and give orders for its execution: it is essential that there be careful independent checking of results. The extensive work of the Yellow Fever Service throughout Brazil over a number of years gave an unexcelled opportunity for the development of a careful administrative technique and the training of a highly selected personnel for the application of this technique to the problem of mosquito eradication. The value of these elements in the attack on gambiae cannot be overestimated.

Likewise the results obtained by the Yellow Fever Service in the large-scale program for the control of aegypti were important in creating confidence among the officials of the Brazilian Government and The Rockefeller Foundation responsible for voting funds and approving plans for the gambiae eradication campaign.

INVASION OF MORE FAVORABLE REGIONS

Although it had been shown in 1934 and 1935 that gambiae had survived the 1932 drought, persisting in the well-watered coastal area close to Natal as well as along the coast farther north (Touros), no evidence of extension to new areas was found until September 1937 when the Yellow Fever Service picked it up at Barreiras near the mouth of the Assú River. It is interesting to note that this discovery of gambiae was due to the finding of aegypti larvae in Macau, in barrels of water coming from Barreiras. An investigation in that village revealed the presence of gambiae larvae as well as those of aegypti. Later the adult gambiae was found in Macau and it has been suggested that it too came on the boat which brought fresh water from Barreiras, although the reverse may have been true, and Macau may actually have been infested before Barreiras. The Yellow Fever Service did not report any farther extension of gambiae until it was found in March of 1938 at various points in the lower Jaguaribe valley.

The data submitted by the Yellow Fever Service are not sufficient to fix with any certainty the date or route of infestation of the Assú or Apodí valleys in Rio Grande do Norte.

DATE AND ROUTE OF INVASION OF CEARÁ

From the extent of the area of the lower Jaguaribe valley involved in the 1938 epidemic, it seems that a considerable period, possibly a year or more, must have intervened between the introduction of gambiae into the State of Ceará and the occurrence of that major catastrophe. On the other hand, it seems reasonably certain from the evidence to be presented, that gambiae was not actively transmitting malaria in the Jaguaribe valley previous to the year 1937.

Clinical Observations

Souza Pinto (Lecture in Fortaleza, Ceará, June 1938) referred to a serious outbreak of malaria at Aracatí near the mouth of the Jaguaribe in 1937 and stated definitely that gambiae had entered the Jaguaribe valley by the sea route. Castro Meireles, a practicing physician in Aracatí, believed however that União, on the lower Jaguaribe, had been infested from Areias in 1936 and that Aracatí had been infested from União. He states that the first epidemic in Aracatí occurred in February 1937. On the other hand, Belo da Mota, in a report of the Ceará Public Health Department, September 1939, described the extension of gambiae-borne malaria to the neighborhood of the city of Aracatí "possibly last year (1938) when malaria became a serious matter there and at União" (Fig. 25).

Blood Examinations

In February 1936 the Division for Studies on Endemic Diseases, of the Oswaldo Cruz Institute, in the course of studies of visceral leishmaniasis (kala-azar) at Timbaúbas, in the county of Russas, examined fifty blood smears from a district in which the presence of the malaria parasite was later, under the influence of gambiae, to become 100 per cent, without finding any positives. Gambiae-transmitted malaria was first observed as a serious epidemic in Russas in March 1938, some time after both União and Aracatí had paid a heavy toll to the disease (E. Chagas 1938).

Liver Examinations

An analysis of the data based on the evidence of malaria in the liver tissues collected by the Viscerotomy Section of the Yellow Fever Service in the lower Jaguaribe valley indicates clearly that gambiae-transmitted malaria had become an appreciable cause of death at several points as early as during the first six months of 1937, even before its presence had been registered for Macau and Barreiras, which have been considered as steppingstones for gambiae on its route from Natal to the Jaguaribe valley.

In considering the data from the viscerotomy records, it must always be remembered that viscerotomy is organized and maintained by the Yellow Fever Service primarily for the purpose of discovering otherwise unrecognized outbreaks of yellow fever. Thus, only bodies in which death has occurred after a short febrile

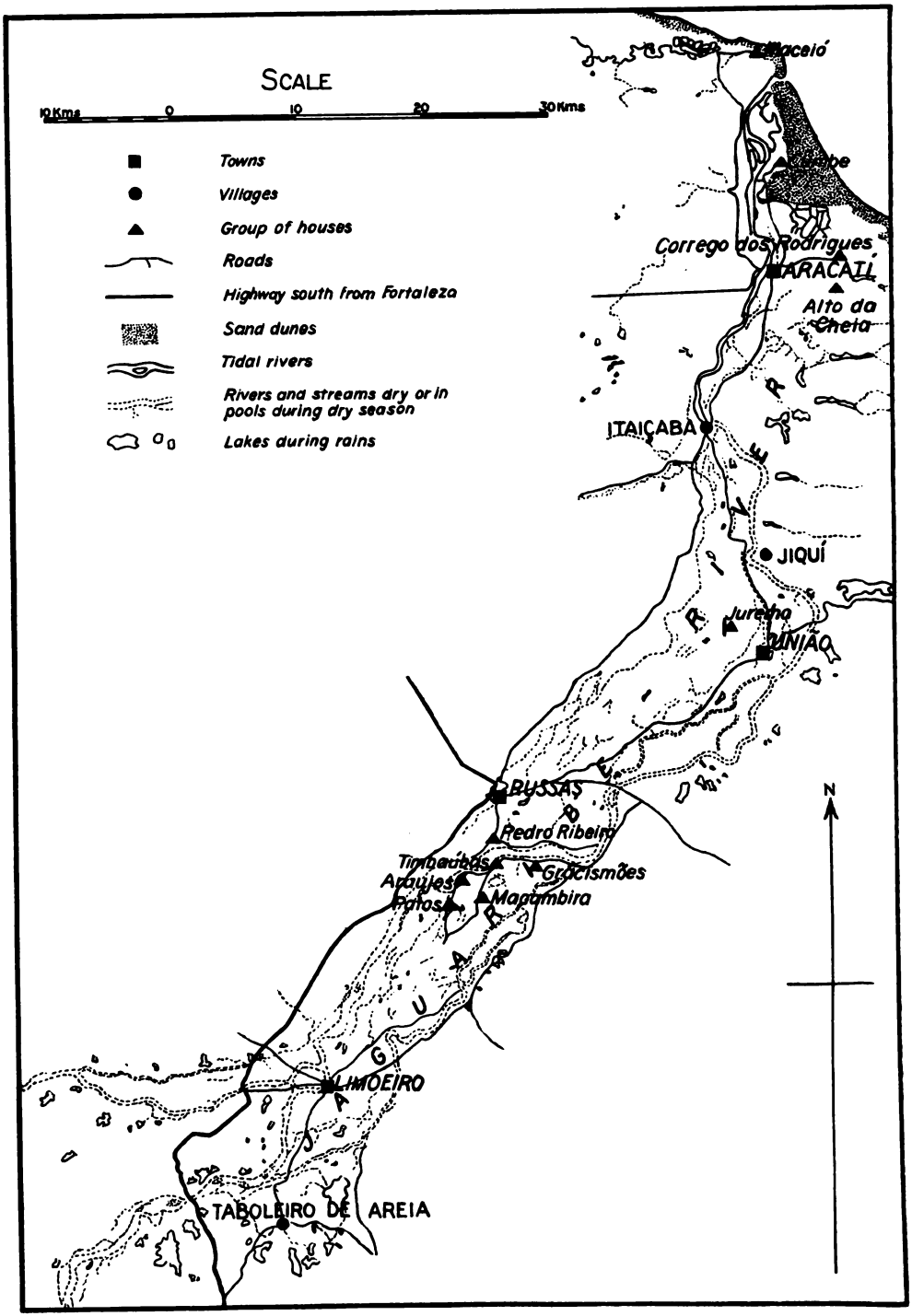


FIG. 25.—Lower Jaguaribe valley.

illness are viscerotomized and collections of specimens can be discontinued in an area at any time the Yellow Fever Service becomes convinced that yellow fever is entirely absent from that area, or for reasons of shortage of budget or personnel. Unfortunately the peak of the 1938 malaria epidemic coincided with the unexpected inclusion of the State of São Paulo in the zone of operations of the Yellow Fever Service but without a corresponding increase in the annual budget. The necessary temporary adjustment was made in part by suspending viscerotomy throughout much of Northeast Brazil, with the result that data are lacking for many places after June 1938. In spite of these lacunae, it is possible from existing data to state that:

Prior to the arrival of gambiae in Ceará, malaria was not a serious problem in the Jaguaribe valley, but was a significant cause of mortality in the well-watered region along the coast close to Fortaleza and in the upper northwest corner of the state (Table 10).

Gambiae-transmitted malaria became important almost simultaneously at Russas, União, and Itaiçaba (Passagem de Pedras) in April and May 1937. During 1938 practically all of the lower Jaguaribe valley was involved and extensions had already occurred to the River Banabuiú and to the middle Jaguaribe as far as Jaguaribe Mirím (Table 11).

In 1939 malaria proceeded up the Salgado and upper Jaguaribe and also continued as a killing disease in the lower reaches of the river (Table 12).

No corresponding increase in livers showing lesions of malaria was registered for areas in those parts of the state where gambiae failed to penetrate (Table 10).

MECHANISM OF INVASION OF CEARÁ

How gambiae came to the Jaguaribe valley is subject to controversy. It may have been brought into the region on one of the innumerable sailboats (Fig. 26) that ply along the coast to Aracatí and up the river to Itaiçaba, head of the navigation on the Jaguaribe River in the dry season. Itaiçaba lies thirty kilometers

TABLE 10

LIVER SECTIONS SHOWING MALARIA

Viscerotomy Returns

GAMBIAE AREA	1932		1933		1934		1935		1936		1937		1938		1939		1940		1941	
	LIVER EXAMINED	MALARIA	LIVER EXAMINED	MALARIA	LIVER EXAMINED	MALARIA	LIVER EXAMINED	MALARIA	LIVER EXAMINED	MALARIA	LIVER EXAMINED	MALARIA	LIVER EXAMINED	MALARIA	LIVER EXAMINED	MALARIA	LIVER EXAMINED	MALARIA	LIVER EXAMINED	MALARIA
Lower Jaguaribe																				
Aracatí	52	0	30	0	9	0	16	0	12	0	19	1	36*	6*	†	†	†	†	†	†
Passagem de Pedras (Itaiçaba)	7	1	57	0	21	0	18	1	14	1	79	16	69	22	†	†	†	†	†	†
Jiquí	†	†	†	†	2	0	8	1	12	0	16	3	46	12	13	6	11	2	10	1
União	74	0	208	0	54	0	50	4	73	0	139	20	143‡	34‡	†	†	†	†	†	†
Russas	71	0	40	0	54	0	71	3	107	0	165	17	219‡	61‡	†	†	†	†	†	†
Limoeiro	46	0	149	1	31	1	45	1	45	0	53	2	61‡	22‡	†	†	†	†	†	†
Banabuiú River																				
Morada Nova	11	0	24	0	12	0	23	0	21	0	8	0	23	5	33	9	18	0	20	1
Quixeramobim	49	0	3	0	14	0	10	0	6	0	4	0	4	0	10	2	18	1	18	0
Mulungú	†	†	†	†	†	†	7	0	9	0	16	0	19	1	40	10	25	7	16	3
Afonso Pena	12	0	8	0	24	1	17	0	16	0	15	0	20	0	28	3	29	2	30	5
Riacho de Sangue																				
Riacho de Sangue	12	0	2	0	1	0	11	0	5	0	7	0	12	2	31	16	20	3	13	1
Cachoeira	7	0	†	0	9	0	16	0	9	0	5	0	10	0	15	5	10	0	18	0
Middle Jaguaribe																				
Jaguaribe Mirím	43	0	24	0	5	0	15	0	3	0	10	0	6	1	†	†	†	†	†	†
Bomfim	†	†	†	†	†	†	5	0	9	0	9	0	13	0	21	12	8	1	10	2
Salgado River																				
Icó	47	0	18	0	13	0	34	0	11	0	23	1	9	0	20	5	22	4	13	0
Upper Jaguaribe																				
Bom Jesus (below Iguatú)	†	†	†	†	†	†	53	0	37	0	18	0	8	0	20	5	10	2	17	0
Iguatú	45	0	118	0	85	3	156	1	129	0	108	0	62	0	†	†	†	†	†	†
Total	476	1	681	1	334	5	555	11	518	1	694	60	760	166	231	73	171	22	165	13

OUTSIDE GAMBIAE AREA																													
Fortaleza Zone																													
Mecejana	76	0	109	15	66	23	101	15	44	2	40	0	26	4	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†
Aquiraz	†	†	†	†	25	1	87	12	65	0	66	6	29	4	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†
Cascavel	35	0	98	1	64	2	56	5	55	2	40	1	41	3	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†
Upper Northwest Corner of State																													
Sobral	63	0	108	0	22	9	54	8	80	2	30	1	11	0	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†
Santana do Acaraú	7	0	34	7	27	13	5	3	7	0	4	0	1	0	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†
Santa Cruz do Acaraú	†	†	†	†	†	†	1	0	7	0	9	0	15	1	26	7	22	4	25	1	1	0	0	0	0	0	0	0	0
Acaraú	7	0	7	1	4	0	8	2	5	0	10	0	11	0	18	0	13	0	10	1	1	0	0	0	0	0	0	0	0
Massapé	9	2	17	2	40	17	27	8	37	1	65	3	31	1	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†
Riachão	†	†	†	†	†	†	1	1	2	0	4	0	10	0	12	4	18	4	9	2	2	0	0	0	0	0	0	0	0
Granja	6	0	6	0	5	2	4	0	3	0	7	0	10	0	11	4	11	4	13	0	0	0	0	0	0	0	0	0	0
Camocim	31	0	91	4	13	5	16	0	6	0	6	0	4	0	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†
Palma	†	†	1	0	2	0	2	1	2	0	3	0	11	0	12	4	9	3	8	2	2	0	0	0	0	0	0	0	0
Viçosa	1	0	1	0	69	10	23	8	13	0	22	3	14	2	7	0	13	0	15	1	1	0	0	0	0	0	0	0	0
Ibiapina	†	†	†	†	10	0	11	1	31	1	21	1	7	1	20	2	17	0	9	0	0	0	0	0	0	0	0	0	0
Total	235	2	472	30	347	82	396	64	357	8	327	15	221	16	106	21	103	15	89	7	6	0	0	0	0	0	0	0	0

* 5 months only; viscerotomy post closed.
† Viscerotomy post not functioning.
‡ Six months only; viscerotomy post closed.

TABLE 11

LIVERS WITH MALARIA LESIONS

Lower Jaguaribe

LOCALITY	LIVERS	TOTAL 1936	1937												TOTAL 1937	1938												TOTAL		
			J	F	M	A	M	J	J	A	S	O	N	D		J	F	M	A	M	J	J	A	S	O	N	D	1938	1939	1940
Aracatí	Examined	12	0	2	4	1	1	2	2	0	2	0	1	4	19	1	4	0	20	11	—	—	—	—	—	—	—	36*	—	—
	Positive	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	1	4	—	—	—	—	—	—	—	6*	—	—
Itaiçaba	Examined	14	6	0	6	10	11	7	8	4	8	6	5	8	79	13	4	6	20	25	1	—	—	—	—	—	—	69*	—	—
	Positive	1	0	0	0	0	1	0	5	1	2	0	0	7	16	5	4	0	3	9	1	—	—	—	—	—	—	22*	—	—
Jiquí	Examined	12	0	0	2	0	0	0	0	5	1	1	1	6	16	8	1	3	7	13	2	2	5	2	1	1	1	46	13	11
	Positive	0	0	0	0	0	0	0	0	0	1	0	0	2	3	3	0	1	1	4	0	1	1	0	0	1	0	12	6	2
União	Examined	73	15	6	16	12	14	6	9	12	6	13	13	17	139	15	18	15	32	57	6	—	—	—	—	—	—	143*	—	—
	Positive	0	0	0	0	3	0	0	1	3	2	2	2	7	20	4	4	4	0	19	3	—	—	—	—	—	—	34*	—	—
Russas	Examined	107	12	9	15	12	13	9	8	7	9	15	26	30	165	20	20	12	46	98	20	1	—	—	—	—	—	217*	—	—
	Positive	0	0	0	0	1	0	1	1	0	2	2	2	8	17	6	3	5	2	41	5	0	—	—	—	—	—	62*	—	—
Limoeiro	Examined	45	3	3	6	9	13	4	2	2	1	3	2	5	53	3	5	6	14	31	2	—	—	—	—	—	—	61*	—	—
	Positive	0	0	0	0	1	0	0	0	0	0	1	0	0	2	0	0	0	2	21	0	—	—	—	—	—	—	23*	—	—

* Viscerotomy suspended after the middle of the year.

TABLE 12

LIVERS WITH MALARIA LESIONS

Upper Jaguaribe

LOCALITY	LIVERS	TOTAL		1938												TOTAL 1938	1939											TOTAL	
		1936	1937	J	F	M	A	M	J	J	A	S	O	N	D		J	F	M	A	M	J	J	A	S	O	N	D	1939	1940
Morada Nova	Examined	21	8	2	0	0	2	1	8	0	2	3	2	1	2	23	3	1	6	3	4	4	2	0	3	2	2	3	33	18
	Positive	0	0	1	0	0	0	1	1	0	0	2	0	0	0	5	0	0	1	0	0	2	2	0	2	0	1	1	9	0
Quixeramobim	Examined	6	4	1	0	0	0	1	0	0	1	0	0	1	0	4	0	0	3	0	2	1	0	0	2	1	0	1	10	18
	Positive	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	2	1
Mulungú	Examined	9	16	1	2	2	1	2	1	2	1	2	2	1	2	19	3	2	3	3	4	3	4	4	3	4	3	4	40	25
	Positive	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	1	3	2	1	0	1	1	10	7
Afonso Pena	Examined	16	15	1	1	1	2	4	1	1	2	0	2	4	1	20	2	3	3	4	4	1	0	4	2	1	2	2	28	29
	Positive	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	3	2
Frade	Examined	5	7	3	1	1	1	1	1	0	2	2	0	0	0	12	1	3	2	3	4	3	4	3	2	3	3	0	31	20
	Positive	0	0	0	0	0	0	0	1	0	0	1	0	0	0	2	0	0	0	1	2	3	4	3	1	1	1	0	16	3
Cachoeira	Examined	9	5	1	1	1	1	1	0	1	0	1	0	1	2	10	0	0	2	4	0	1	1	3	1	0	1	2	15	10
	Positive	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	1	1	5	0
Jaguaribe Mirím	Examined	3	10	1	2	1	0	2	—	—	—	—	—	—	—	6*	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Positive	0	0	0	0	0	0	1	—	—	—	—	—	—	—	1*	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bomfim	Examined	9	9	2	1	1	0	5	2	0	1	0	1	0	0	13	0	2	2	0	0	2	3	3	2	3	1	3	21	8
	Positive	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	2	2	1	2	12	1
Icó	Examined	11	23	0	1	0	4	1	1	0	1	0	0	1	0	9	1	0	1	1	5	3	1	2	2	3	1	0	20	22
	Positive	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	0	1	0	0	0	0	5	4
Bom Jesus†	Examined	37	18	0	2	0	2	0	1	0	1	0	1	0	1	8	0	1	5	1	1	0	2	0	2	4	2	2	20	10
	Positive	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3	1	0	5	2
Iguatú	Examined	129	108	14	12	13	12	10	1	—	—	—	—	—	—	62*	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Positive	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—

* Viscerotomy suspended after the middle of the year.

† Below Iguatú.

FIG. 26.—Sailboats ply along the northeast coast.

from the mouth of the river at a point where an outcrop of rocks forms a natural dam, which is above the level of the tide during the dry season. Along both banks of the river there is plenty of subsoil water which is pumped to the surface by windmills, with consequent potential man-made foci for gambiae production (Fig. 27). Breeding possibilities are even greater in the valley above Itaiçaba. In addition to the pumped water, there are many residual pools in the river bed. It would have been very easy for gambiae, once it reached Itaiçaba, to breed its way up the valley, while slowly establishing itself in the estuary region around Aracatí at the same time.

An alternative theory is that gambiae was brought into the Jaguaribe valley by one of the many motor vehicles which carry freight and passengers along the highway from Natal to Fortaleza, passing through Limoeiro and Russas. Russas is on the direct route from Rio Grande do Norte to Fortaleza, but the detour through União is used constantly because of the greater facilities for crossing the Jaguaribe River at that point, especially during the dry

season. Breeding conditions are ideal in that area throughout the year and gambiae would have had little difficulty in immediately establishing itself there. Its spread up and down the river was then only a question of time, for the thickly populated river banks with houses always within gambiae flight one from another, the numerous pools and caçimbas in the river bed itself, and the shallow ponds and puddles (Figs. 28, 29, 30) away from the river, make it one of the most favorable breeding regions in Northeast Brazil.

EPIDEMIC MALARIA IN THE NORTHEAST

"It was like an epidemic of plague or cholera," wrote Ross describing the outbreak of malaria which occurred in the Island of Mauritius in 1866-67. "One quarter of the inhabitants of Port Louis died from all causes in 1867 and 6,224 out of a population of 87,000 in one month (April). The whole death rate of the Island

FIG. 27.—Windmill and irrigation ditch.

rose from 32/1,000 in 1866 to 120/1,000 in 1867 . . ." (Ross 1910). Ross and others who studied the catastrophe in Mauritius, where epidemic malaria had been unknown prior to 1865, attribute it to invasion of that island by *A. gambiae.*

The tragic experience of Mauritius had a faint echo in the Natal epidemic of 1930-31, but it was not until seven years later, after gambiae had reached the highly favorable Assú, Apodí, and Jaguaribe valleys, that the full tragedy of Mauritius was reenacted in Brazil. In 1938 these river valleys were the scene of epidemic malaria equal in severity, if not in extent, to that of the worst outbreaks described in the literature of this disease:

> The human language is far from adequate to describe the desolation which existed in the region, in which suffering, tears and mourning spread their lugubrious mantle over thousands of graves. The general belief was that the Northeast would be depopulated because those who did not die at once would abandon it (*Gazeta de Noticias,* Fortaleza, April 11, 1940).

Entire families were laid low at one time. Often none were spared to cook the little food available or to seek more; none were able to go for medicine, even had there been money with which to buy it. In regions where malaria is unknown, not only does the local population completely lack immunity to the disease but there exists almost total ignorance as to the possibility and necessity of suitable treatment. Nevertheless, the local stocks of adulterated quinine were rapidly exhausted, at exorbitant prices, as were also very shortly the stocks of quinine and atabrin supplied by the state government. In a population always suffering from undernourishment, the inability to work for even a few days, resulted in further reduction of food supplies, entailing in many cases complete absence of food. Illness, poverty, hunger, starvation, and death were all close associates in this fulminant epidemic of Northeast Brazil. The accounts of eyewitnesses, those public health officials who attempted to cope with the catastrophe, reveal a truly desolate picture.

RIO GRANDE DO NORTE

The Federal Health Delegate in Rio Grande do Norte, Dr. Valerio Konder, wrote as follows:

FIG. 28.—Shallow pond on carnauba flats.

FIG. 29.—Residual rainwater on carnauba flats.

FIG. 30.—Another view of carnauba flats under water.

(May 20, 1938. Before visiting the stricken area)

After 1930, the year in which gambiae appeared in Natal, the (malaria) situation became much worse. . . . In 1931 the village of São Gonçalo was almost depopulated, the valley of the Ceará Mirím having also been greatly stricken. During these last eight years, fifteen counties (in Rio Grande do Norte) have been invaded by costalis (sic) and this year it is responsible for an epidemic in the Assú valley . . . where there are about 5,000 sick. At the same time we are informed of the greatest malaria epidemic in the history of the Northeast—that now raging in the Jaguaribe valley, in Ceará, where daily some eighty people die.

(June 1938. After first visit to epidemic zone)

The present outbreak of malaria caused by *A. gambiae* covers the entire coast of Rio Grande do Norte and especially the three great valleys of the Ceará Mirím, Assú, and Mossoró (also called Apodí) rivers. . . . There are about 40,000 sick in Rio Grande do Norte.

A wholesale exodus took place from infested to clean areas and to towns where medical care might be available. In Baixa Verde, where 425 of 951 houses were closed, a survey of 263 houses showed that 1,012 persons out of about 1,060 were ill. In another village, Santa Luzia, the situation found was even worse, since of 100 dwellings half were abandoned, and of "some four hundred inhabitants, some four hundred were ill."

(July 1938)

The situation grows worse from day to day. . . . In traveling sixty kilometers through the river lowlands, our car followed a trail on which houses were never more than 500 meters apart. We stopped at more than ten different points inquiring for someone who had not yet had fever; we failed to find any such person.

Not only was everyone ill, but the mortality was appalling. The economic life of the region was disrupted (Fig. 31) and malaria took its toll of whole families who were practically starving.

(July 11, 1938. At Assú)

The chief local authority, Dr. Pedro Amorim, places the loss on the cotton crop at 70 per cent, the reduction in the extraction of carnauba wax at 80 per cent, with a similar falling off in the salt production. The entire population is very poor, living from hand to mouth on the day's wages; on the day a man does not work, he and his family do not eat. This is one of the principal causes of the high mortality of this outbreak of malaria, many of

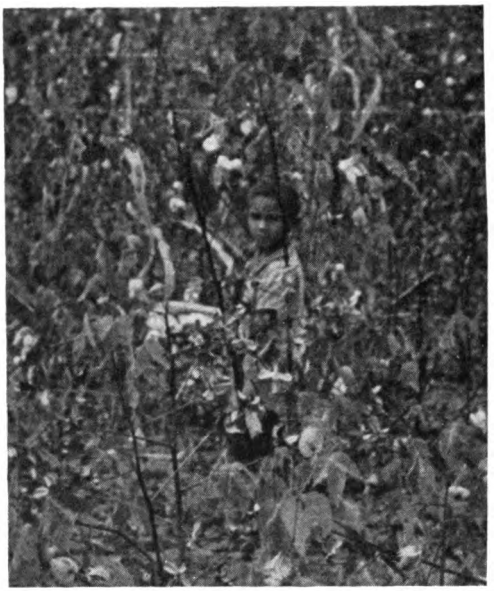


FIG. 31.—Entire family stricken, small boy tries to pick cotton.

the deaths being due to starvation as well as to lack of treatment. This population is entirely ignorant regarding malaria and the mosquito transmission of malaria which is currently referred to as "the new disease."

The trip was a truly depressing experience since we saw entire families along the road, blocking the passage of the car as they begged for medicine.

(July 12, 1938)

We traveled once more through the lowlands by another route, partly along the bed of the river which was almost dry. The same spectacle of desolation and suffering, the same picture of an entire population ill and violently decimated by sickness and hunger. . . . We traveled in the lowlands of the Assú in four directions and, except for Rosario, the fever is everywhere. The mortality has been terrific; in Santa Luzia, center of a zone with 2,000 cases, the local cemetery has received 232 dead in the past two months. A new cemetery, opened in Sacramento on June 6, has already had 88 burials. Sacramento is the center of a zone with less than 1,500 people.

Burial outside the regular cemeteries is not uncommon in the interior of Brazil, and it can therefore be assumed that deaths exceeded the number registered.

(Continuing, July 12, 1938)

On one side of the Assú valley there are, as has been noted, 20,000 cases; on the other side 12,000 (Macau 3,000, Angicos 1,000, Santana do Matos 8,000),

or a total of 32,000. The estimated mortality is 10 per cent, which shows how serious is the malaria found here as well as the contributing causes, hunger and poverty.

It would take too long to narrate here all the sad details of the trip through this stricken region where it took will power to continue the program of investigation instead of giving way to the insistence of the ragged and hungry multitude which pleads for mercy at the side of the road, trying to block our passage and to induce us to examine the sick who were dying in near-by houses.

For the State of Rio Grande do Norte, Konder and Souza Pinto respectively, estimated 46,000 and 51,500 cases of malaria. Souza Pinto (July 1938) also attempted to estimate the deaths from malaria in that state. The figures are given below:

TABLE 13

Rio Grande do Norte	POPULATION DECEMBER 1937	ESTIMATED CASES		ESTIMATED FATALITIES
		Konder	Souza Pinto	Souza Pinto
Areia Branca	13,793	5,000	3,000	210
Mossoró	30,576	2,000	500	
Assú	37,313	20,000	20,000	2,100
Macau	22,107	3,000	3,500	440
Angicos	18,866	1,000	1,000	980
Santana do Matos	29,570	8,000	9,000	
São Gonçalo	23,860	—	1,500	—
Ceará Mirím, Taipú, and Baixa Verde	67,623	7,000	13,000	1,560
Total	243,708	46,000	51,500	5,290

It should be noted that these, as well as the Ceará estimates which follow, are as of the midyear 1938.

1938 EPIDEMIC IN CEARÁ

In the State of Ceará, along the valley of the Jaguaribe, the picture was identical, if not worse, due to the greater area involved.

According to Belo da Mota (Report 1938), early in April 1938 the health authorities in the capital of the state received complaints from the lower Jaguaribe of a serious epidemic raging

through the counties of Aracatí, União, Russas, Morada Nova, and Limoeiro, which seemed to be malaria although accompanied by an unaccustomed series of unknown and severe symptoms. Field investigations begun on April 13 revealed a desolate picture:

> Hour by hour, day by day, the number of the sick increased. The stock of medicines rapidly gave out. It was impossible to make a survey of the region. The incessant rains transformed the terrain into one big lake. All the Jaguaribe lowlands were an immense sheet of water. The roads disappeared under water, making it impossible for vehicles to move. From the near-by counties came constant pleas for doctors and medicine. Toward the middle of June the rains stopped and the flood began to subside, but the collections of water which remained in the depressions of the terrain were infinite in number and in these foci of gambiae larvae abounded.

In June 1938, E. Chagas (1939), director of the Division for Studies on Endemic Diseases, found that at Russas, where malaria had been unimportant in February 1936, a most serious malaria problem had developed. Practically the entire rural population was infected.

TABLE 14

RUSSAS	BLOODS			SPLEENS		
	Examined	Positive	Percentage	Examined	Positive	Percentage
February 1936	50	0	0.0	50	3	6.0
June 1938	203	164	80.8	478	175	36.6

The rural areas seemed to have been the first attacked by malaria which later spread to the small towns and larger cities as the population fled there for treatment. Misery reached its maximum and often people were treated who had been without food for four or more days. Death occurred even in cases of benign tertian malaria. The more fortunate families went to the cities, the poorer families to near-by areas, often taking parasites with them just ahead of the gambiae, thus paving the way for the ensuing epidemic.

Souza Pinto calculated in July 1938 that in the lower Jaguaribe valley there were about 63,000 cases of malaria, distributed as follows:

	Cases of Malaria
Russas	20,000
União	18,000
Limoeiro	10,000
Morada Nova	10,000
Aracatí	5,000

Whole households were wiped out; estimated deaths up to that time and in that region numbered 8,000. It was calculated that in the two counties of União and Russas over 90 per cent of the population, both rural and urban, was ill. Traveling salesmen and other representatives of business concerns refused to visit the region, and any organization working or planning to work in the Jaguaribe valley had to make definite plans for protecting the health of its employees. The region was fast taking on the aspect referred to by Ross: "Very malarious places cannot be prosperous: the wealthy shun them, those who remain are too sickly for hard work; and such localities often end by being deserted by all save a few miserable inhabitants."

The situation became so desperate that the state government remitted taxes in the lower Jaguaribe valley; a local holiday was decreed and a special Mass held in Russas following the first day, in August 1938, on which no death from malaria was registered in the town.

The State Public Health Service, in spite of difficulties of travel and shortage of personnel and drugs, treated some sixty

TABLE 15

CEARÁ TREATMENTS, 1938

(*According to Belo da Mota*)

CEARÁ	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	TOTAL
Russas	3,800	5,400	4,100	3,900	1,500	1,100	700	20,500
Limoeiro	—	—	850	4,100	4,000	3,440	2,400	14,790
União	2,500	2,600	2,400	1,100	700	400	200	9,900
Morada Nova	900	1,400	1,100	1,800	1,400	1,500	1,000	9,100
P. de Pedras	—	—	600	1,400	500	100	100	2,700
Riacho de Sangue	—	—	—	1,000	700	600	400	2,700
Total	7,200	9,400	9,050	13,300	8,800	7,140	4,800	59,690

thousand persons in its dispensaries from April to October, before the organization of the Antimalaria Service in October by the federal government.

In an article on gambiae-borne malaria, P. A. Sampaio complained of the lack of official data and estimated that, "in this march from Natal, up the coast and along the Jaguaribe valley nearly one hundred thousand people became infected with malaria, of whom about twenty thousand died. Like hordes of bloodthirsty Huns the mosquitoes advance, leaving always a trail of mourning[1] and destruction in their wake."

EPIDEMIC VS. ENDEMIC MALARIA

Reliable mortality statistics are always difficult to obtain in the smaller cities and towns and practically impossible for many rural districts. The Yellow Fever Service, in promoting the development of viscerotomy, had forced the closing of many small clandestine cemeteries and established a distance of eighteen kilometers between licensed cemeteries. During the 1938 epidemic, however, the transportation of the dead to the central cemeteries became impossible because of the number of those ill, and local authorities had no choice but to permit the opening of unregistered emergency cemeteries (Fig. 32).

From the reports cited above it will be seen that health officials visiting the stricken areas of Ceará and Rio Grande do Norte at the height of the epidemic period in June and July made a rough estimate for the two states of approximately one hundred thousand cases with a mortality of between fourteen thousand and twenty thousand persons. When it is remembered that conditions favorable to transmission continued for a number of months after this peak period, and that one of us (F.L.S.) was infected while on a few days' visit to the infected area as late as the second half of November, it is reasonable to believe that the estimates given

[1] As mourning in Brazil is marked by the wearing of black, the phrase "trail of mourning" should be taken literally; in traveling through the area practically everyone seen was wearing black in tribute to close relatives lost.

are not exaggerated if applied to the entire year 1938. In support of this is the experience of 1939 when more than 185,000 persons were registered and treated for malaria.

Although at times very severe, malaria in Brazil, in the absence of gambiae, never reaches the epidemic intensity attained in Northeast Brazil in 1938 and 1939. Those who have not seen malaria under epidemic conditions cannot realize how much more terrifying it can be than is endemic malaria. Physicians and health officers familiar only with endemic malaria and its seasonal exacerbations could not recognize the disaster they saw as due to the same disease: it was incredible that it was only a new vector and not a new African disease which had been imported.

It must be borne in mind that the bulk of observations compiled during investigations of malaria refer to endemic malaria, which generally shows a normal annual or seasonal wave of morbidity and mortality. The term epidemic malaria should not be applied to this seasonal wave but only to outbreaks of special intensity in the population studied. Gill uses the term "fulminant epidemic" for those outbreaks associated with "almost universal sickness and

FIG. 32.—Emergency cemetery.

a death rate many times the normal." Fulminant epidemics are rare and occur "under instances where a great relative decrease in immunity is associated with a marked temporary increase in the amount of infection." Previous to the 1938 outbreak of Northeast Brazil there had been no obviously important decrease in immunity since little or none existed but, on the other hand, a marked increase in the amount of infection due to the introduction of a new and very efficient vector had occurred. This outbreak readily qualifies as fulminant epidemic malaria since it was of "so violent and explosive a nature as to involve the major portion of the population and cause a very heavy mortality." It must be classed with the epidemics that decimated Mauritius in 1867, the Punjab in 1908, and Ceylon in 1935. Since gambiae apparently has been eliminated from the region, we may consider the experience in Northeast Brazil as true epidemic malaria, but had gambiae been allowed to persist, a series of severe epidemics would have continued to occur in one region after another as each was in turn invaded, followed by a sinking of these areas to a lower level of economic development with a high level of permanent malarial endemicity.

SURVEYS AND CONTROL MEASURES

LOCAL MEASURES

The local health authorities were totally unprepared for an outbreak of malaria such as that of 1938, but Drs. Armando China, director of health of Rio Grande do Norte, Virgilio Uzeda, director of health for Ceará, and Valerio Konder, assisted by Belo da Mota, launched inadequately financed campaigns devoted mainly to the distribution of food and drugs to the sick.

INITIAL SURVEYS

As early as May 1938 the state governments made an appeal to the federal government for aid in organizing and financing the

campaign against *A. gambiae*. Souza Pinto was designated to investigate the situation on behalf of the National Health Department. A five-week field trip was followed by a report (July) recommending organization of a federal service with a budget of 1,000 contos (about $50,000 U.S.) for control work in Rio Grande do Norte and Ceará during the remainder of 1938.

E. Chagas made an independent survey of the extent of the infested area and called attention in no uncertain terms to the disaster which had overtaken Northeast Brazil and which threatened the rest of the continent (September 1938).

ANTIMALARIA SERVICE

On August 5, 1938, the President of Brazil, Getulio Vargas, signed a decree organizing the Antimalaria Service, with a budget of 1,000 contos as suggested, to undertake the control of gambiae-transmitted malaria.

On October 28, the medical staff of this Service, under Dr. Manoel Ferreira, arrived in Northeast Brazil and began hiring and training personnel and purchasing material needed for the installation of field posts for the treatment of the sick, epidemiological investigations, and antigambiae measures. On November 14, the medical personnel arrived in the infested areas of the Jaguaribe valley. On November 30, Dr. Cesar Pinto, of the Oswaldo Cruz Institute, arrived in Natal to install the laboratory of the Service (Cesar Pinto 1939).

It is to be regretted that no official report of the difficulties encountered by this organization during its two months' activities in the field has been published. Microscopes, laboratory material, and other equipment, ordered from Rio weeks before, did not begin to arrive until toward the end of November. All subordinate personnel had to be trained for the various types of specialized work needed, from microscopy to the search for larval foci. Day laborers only were easy to secure. The clamor from the malaria-stricken population was so great that treatment of the sick could not be ignored, with the result that a large proportion of the

budget was absorbed by the purchase of drugs and by the distribution of quinine and atabrin. In spite of these difficulties, however, much useful work was done. In Rio Grande do Norte it was shown that Natal itself was still free of gambiae seven years after the termination of the original campaign there, but that on the other hand the São Gonçalo section of the Potengí estuary was heavily infested and that the most important foci there were the long-neglected drainage ditches dug during the initial antigambiae campaign at the time (1931-32) that Natal was cleared. The definite range of gambiae was not established in the rest of the state during the year, although divisional headquarters were established in Ceará Mirím and Assú during December. In Ceará, divisional headquarters for the upper, middle, and lower Jaguaribe valley were installed at Icó, Jaguaribe Mirím, and Russas, respectively, in November, and many needy cases of malaria were given atabrin injections.

Direct anti-imaginal measures (spray insecticide or fumigation) were not used by the Antimalaria Service because of a complete lack of equipment and material. Likewise, it was necessary to limit antilarval measures to the cleaning and straightening of river banks, reservoirs, lakes, and drainage ditches, and the filling-in of caçimbas, pools, depressions, and so forth, because Paris green which was ordered late in November had not been received by the end of the year. For continuation of the work of the Antimalaria Service in 1939, Dr. Ferreira asked for an appropriation of 10,000 contos (about $500,000 U.S.).

PRELIMINARIES TO COLLABORATION OF THE ROCKEFELLER FOUNDATION AND MINISTRY OF HEALTH

Even before the organization of the Antimalaria Service the suggestion had been made that the International Health Division of The Rockefeller Foundation, which was already collaborating with the Brazilian Government in the administration of the Yellow Fever Service, might be willing to organize the campaign against *Anopheles gambiae*. In anticipation of such cooperation, the Board

of Scientific Directors of the International Health Division in September 1938 approved the spending of $1,500 for expenses incidental to "a survey which should begin immediately to provide information on which a reasonable proposal for government consideration can be based. . . . A careful survey should be made to secure as much information as possible regarding distribution and those factors in the biology of the mosquito which may be valuable in orienting next year's work." This survey was made by Shannon and Andrade with the aid of two well-trained assistants beginning on October 22 at São Luiz do Maranhão and continuing to the end of the year (Shannon and Andrade, 1940). The results were most important to the planning of the 1939 operations.

In the second half of November a rapid reconnaissance trip was made through the infested valleys of Rio Grande do Norte and the infested region of the Jaguaribe valley in Ceará. The group taking part in this reconnaissance consisted of Drs. Manoel Ferreira, Evandro Chagas, Valerio Konder, Paulo Rouanet, regional director of the Yellow Fever Service, and D. B. Wilson and F. L. Soper of the International Health Division of The Rockefeller Foundation. Shannon and Andrade joined the group in the Jaguaribe valley.

From a compilation of all available data, it seemed possible that gambiae's 1938 range might have been limited to areas indicated on the map on page 155. But it was apparent that such limitation could be only temporary, there being no effective natural barrier to prevent the early invasion of the well-watered Fortaleza, Crato, and Iguatú regions of Ceará and the Cajazeiras area of Paraíba. Each extension would increase the cost of control and at the same time increase the number of points from which further extension might occur.

As a result of this reconnaissance, it was decided that no time should be lost in the proposed program of field study of control methods, but that an attempt should be made to eradicate gambiae before further extension of its range occurred.

Preliminary discussions between representatives of the government and the International Health Division took place in Forta-

leza with, for the government, Drs. João de Barros Barreto, then director of the National Department of Health, who visited the infested region just at that time, and Manoel Ferreira, director of the Antimalaria Service, and for the International Health Division, F. L. Soper and D. B. Wilson. During these discussions it was generally admitted that no one could predict success in an attempt at species eradication, but that those cognizant of the situation in the gambiae-infested areas could predict certain disaster for a large part of Brazil and many other countries on the American continent, should an attempt at eradication not be made.

It was recognized that there were no precedents for a campaign of species eradication except that of the Yellow Fever Service against *Aedes aegypti,* and that no estimates of total cost, nor of time required could be made. It was clear to all that a state of emergency existed which demanded immediate action, since the positions already occupied by gambiae gave it relatively easy access to additional areas, the infestation of which would greatly complicate the problem and increase manifold the difficulties and expense of any attempt at eradication. It was recognized that an initial campaign of this type could be undertaken only by an organization free from all bureaucratic restrictions, with adequate funds and with personnel trained in a large-scale, fine-tooth comb administrative technique. Since at that time only the Yellow Fever Service possessed personnel with the necessary training, it was essential that this Service undertake the task without weighing too carefully the chances for success, but considering only the catastrophic results of failure.

It is a pleasure to record here the attitude of the government representatives in these discussions, both of whom agreed to recommend that the program for the eradication of gambiae be undertaken as a cooperative project even though this would take from them direct administrative control. Manoel Ferreira, whose knowledge of the local situation and of malaria in general were to prove invaluable, agreed to continue as an assistant director of the new Service.

THE MALARIA SERVICE OF THE NORTHEAST

LEGAL BASIS

Although preliminary arrangements had been made and funds for the 1939 antigambiae campaign reserved before the end of 1938, the decree[1] organizing the Malaria Service of the Northeast was not signed until January 11, 1939, nor was the actual contract[2] providing for The Rockefeller Foundation and government collaboration signed until Janaury 31. However, the contract was considered retroactive and the new Service assumed responsibility for operating expenses as of the first of the year. Manoel Ferreira and one of us (D.B.W.) arrived together in Fortaleza on January 14 to effect the transfer of the field services to the new organization.

The total budget of the Malaria Service of the Northeast for 1939 was tentatively set at 7,000 contos (about $350,000 U.S.), 5,000 contos ($250,000 U.S.) of which was contributed by the Brazilian Government, and 2,000 contos ($100,000 U.S.) by The Rockefeller Foundation. By the terms of the contract the Malaria Service of the Northeast absorbed the Antimalaria Service and was able to work with free interchange of material and personnel with the Yellow Fever Service. Although the two organizations were legally distinct, the Malaria Service of the Northeast was at first practically but a branch of the Yellow Fever Service.[3] It is no exaggeration to say that but for the trained personnel obtained from the latter, the rapid success of the Malaria Service of the Northeast would have been impossible.

No special measures were enacted by the state or federal governments to legalize the work of the new organization, since the Presidential Decree No. 21,434 of May 23, 1932, designed by the

[1] Translation of decree, Appendix I.

[2] Translation of contract, Appendix II.

[3] Full advantage was taken of the opportunity to obtain immediate possession of automobiles and other indispensable material belonging to the Yellow Fever Service, while technical personnel, ranging from medical officers, cartographers, accountants, office staff, chief inspectors, and inspectors were drafted freely from this organization.

Yellow Fever Service for its own use (Appendix III), was found to be sufficiently inclusive. In a few places, during the early days of the campaign, county administrators were asked to pass ordinances which provided fines for failure to protect artificial waterholes (caçimbas) from adult mosquitoes.

Relatively little difficulty was encountered in applying the necessary measures throughout the areas where gambiae had shown its power as a vector. The activity of the Yellow Fever Service in the Northeast had already accustomed the people to their homes being visited by inspectors and to the use of larvicides on mosquito foci. Furthermore, gambiae-transmitted malaria was an effective schoolmaster and it was only in frontier areas where gambiae had not penetrated or where, though present, it had not yet produced epidemic malaria that some resistance to the use of Paris green was encountered. Occasionally police force was resorted to, but almost never was legal action necessary. No fines were ever levied for failure to protect caçimbas and the only fine imposed during the three years of the antigambiae campaign was one paid by a driver for passing a disinsectization station without permitting the spraying of his car.

ADMINISTRATIVE ORGANIZATION

Central and Divisional Offices

Office headquarters for the Malaria Service of the Northeast (Fig. 33) were established in Fortaleza, capital of the State of Ceará, with highway, railroad, airplane, and boat communications with the gambiae area. This office handled the correspondence, accounting, statistics, and supplies for the entire gambiae-infested region, receiving reports and distributing supplies through eight[1] field offices. Seven of these were division headquarters, under the director of the division. As the two division offices in Rio Grande do Norte were inland, a third office was established at Natal, the principal port and transportation and banking center of the state, to facilitate communication and shipping between the Central Office and the inland field offices.

[1] Actually nine, since the Maritime Division had its own office organization in the Fortaleza headquarters.

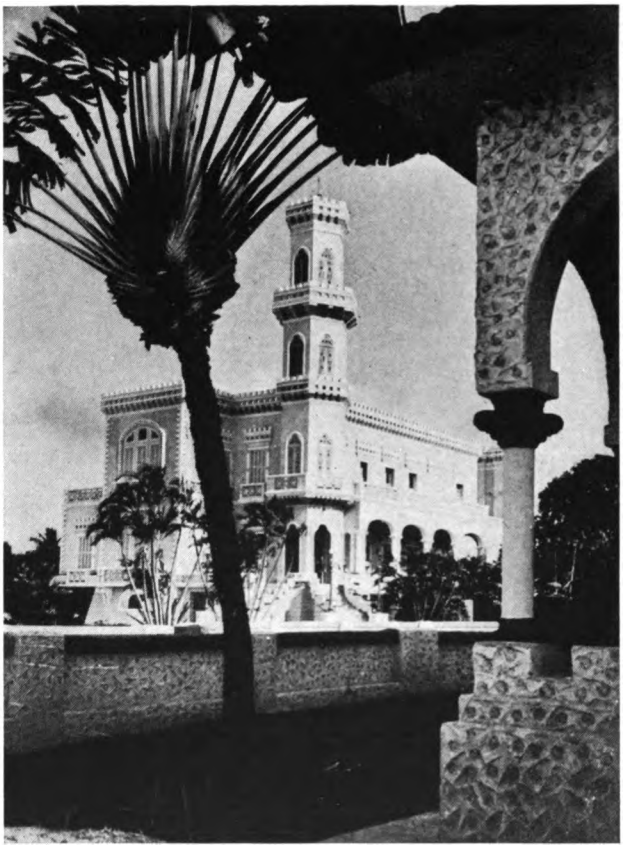


FIG. 33.—Headquarters of the Malaria Service of the Northeast in Fortaleza, Ceará.

CARTOGRAPHIC UNIT

A Cartographic Unit (Fig. 34) was organized with headquarters in Fortaleza. Its first task was to prepare for field use sectional maps of the entire area to be worked. For greater accuracy, air maps of certain sections were made, the air personnel and equipment being furnished by the Military Geographical Service. The necessary groundwork, the developing and printing of the photographs, and the preparation of the final maps were all done by the Cartographic Unit.

LABORATORY AND FIELD STUDY UNITS

Central Laboratory.—The main laboratory was installed at Aracatí (Fig. 35) on the lower Jaguaribe River. This town was

chosen because it was situated well within the most heavily infested area, only four hours distant from Fortaleza by auto, and most of the infested areas of Rio Grande do Norte and Ceará were accessible by automobile. Its principal functions were:

training key men of the field personnel in identification of larvae and adults of gambiae, application of Paris green, house disinsectization, and collection of blood smears for hemoscopic surveys;

testing efficiency of control methods and materials;

identifying mosquito collections, larvae and adults;

examining blood smears (Fig. 36) of annual surveys for determination of parasite rates of 1939, 1940, and 1941;

studying the biology of gambiae: in laboratory colony, and under uncontrolled natural conditions (Cumbe);

studying the biology and determining the distribution of native anopheles.

Epidemiological Section.—The Epidemiological Section was maintained at the Headquarters Office for the investigation of un-

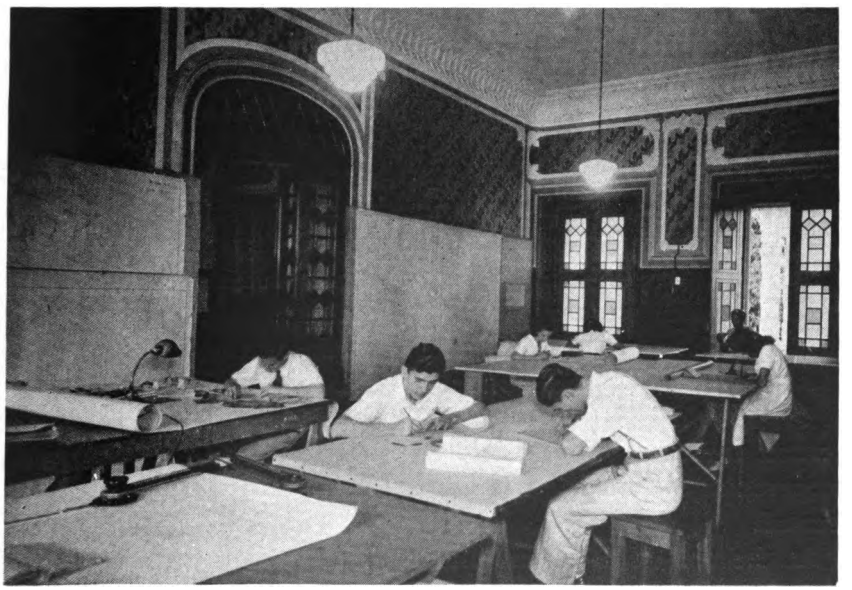


FIG. 34.—Cartographic Unit.

usual outbreaks of malaria which might be reported in areas within possible striking distance of gambiae from the known infested area, and for the collection of material for the annual hemoscopic surveys of malaria incidence.

Cooperation with the Division for Studies on Endemic Diseases.—Before the Malaria Service of the Northeast began field work in the Jaguaribe valley, two small neighboring, heavily populated, semirural areas (Gracismões and Timbaúbas) near Russas were set aside, at the request of the Division for Studies on Endemic Diseases of the Oswaldo Cruz Institute, for the study of gambiae and gambiae-transmitted malaria as affected by regular systematic house disinsectization without antilarval measures. Later the Malaria Service of the Northeast made funds and material available for extension of the studies to include the effect of antilarval measures (Paris green) alone, and the effect of combined antilarval work and house disinsectization at the neighboring villages of Araújos and Macambira. These studies were continued until April 1940 when the progress of the eradication program made it imperative that all natural breeding in this area be stopped as soon as possible.

Administrative Subdivisions

The infested areas in the State of Rio Grande do Norte and Ceará were surveyed by trained chief inspectors from the Yellow Fever Service with many years' experience in fighting *Aedes aegypti* in Brazil, who marked out zones for antilarval work, each of which was put under the undivided responsibility of one inspector.

Zone (Inspector).—An antilarval zone represented the area in which one man could apply larvicide to all potential foci during one week. The zones varied in size in the wet and dry seasons, being small during the former, with its widespread distribution of foci, but large in the latter when only the river beds are important breeding places. As rapidly as possible, zone maps were prepared so that all water collections and houses could be easily located.

At the end of 1939 and the beginning of 1940, when anti-

FIGS. 35 and 36.—Central Laboratory, Aracatí. View of exterior, and examining blood smears.

imaginal measures were introduced, the whole gambiae-infested area was marked out into a second set of zones, each of which contained the number of houses that could be disinsectized during a week by one squad. Since the number of houses was more or less a fixed quantity, the disinsectization zones and, consequently, the squad needed to handle them, did not vary in size according to the season as did the antilarval zones.

District (Chief Inspector).—Since species eradication requires close checking of each inspector's work, chief inspectors were placed over a small number of inspectors (generally five) for whose work they then became personally responsible. The chief inspector was required to see that his inspectors understood their tasks, that they were supplied with necessary materials, and were operating efficiently. The number of zones grouped into a district depended on how many zones under local conditions could be visited and checked by the chief inspector in one week.

Post (Doctor).—A variable number of districts was grouped under the direction of a doctor. Whereas the inspector and chief inspector were responsible for only one type of activity in their zones and districts, the doctor was responsible for the treatment campaign and the antilarval and anti-imaginal services, all of which were based on the zone as a unit.

Division.—A number of posts were grouped to form a division which was always in charge of a doctor of greater experience. At the height of its activity, the Malaria Service of the Northeast had twenty-one posts and seven administrative divisions, five in Ceará (Cascavel, Russas, Jaguaribe, Icó, and Quixadá) and two in Rio Grande do Norte (Assú and Ceará Mirím), besides the somewhat anomalous Maritime Division, which covered the water front from Paraíba to Piauí. As has been mentioned before, each division had its own special office of statistics and supplies. Divisions also possessed laboratory facilities for training personnel and checking material sent in from the field, a map-making service, a dispensary for treating ambulatory cases, and special squads subject to the divisional director, responsible for checking the antilarval and disinsectization work throughout the division as ordered by the director.

Individualization of Responsibility

As in the anti-aegypti campaign of the Yellow Fever Service, the fundamental unit in the gambiae control program was the zone, and whether the individual inspector was engaged in applying antilarval or anti-imaginal measures, or in treating the sick, he alone was held responsible for the efficient performance of his particular task in his zone. In the last analysis it was always the inspector who actually carried out the antigambiae measures and since he often worked alone and far from the post headquarters, it was essential to establish individual responsibility for work done and individual responsibility for checking such work.

To make supervision easy at all times, the inspector followed a fixed itinerary for each day in the week, drawn up by the chief inspector. With the aid of zone maps and markers (Fig. 37) conveniently placed in the zone, there was seldom any reason to deviate from this fixed itinerary. All nonmedical field personnel worked in uniform and carried distinctive flags for marking their location in the zone. The inspector used two flags: the first was placed in a visible position at that point on the highway where he left it (Fig. 38), while the second was used to mark the spot or house where he actually was working. The first flag had a special pocket in which the inspector always left a note of his proposed itinerary for the day, which greatly facilitated finding him in the field at all times.

The chief inspector sometimes accompanied the antilarval or anti-imaginal inspector on his rounds, watching his work and pointing out any defects in his technique, but more commonly he went over the work as a check. Checking the operations of the disinsectization and adult capture squads was facilitated by a visit record, which functioned much as does a night watchman's clock which must be punched at regular intervals. It was posted in some sheltered spot inside every house, and the time, nature, and results of all house visits had to be noted thereon. This record proved to be invaluable since from it the chief inspector could see at a glance how and when the work in a given house had been done. Even the inhabitants often took an interest in following the entries and were free to comment on irregularities.

Although antilarval and anti-imaginal measures were often carried out simultaneously, each service had its own specialized personnel. The antilarval inspectors were responsible only for the application of Paris green to all potential breeding places in their zones, and the chief inspector of that service was responsible only for checking on the larvae breeding and on the work of the antilarval inspectors of his district. Likewise the disinsectization squads were responsible only for the careful spraying of the houses in their zones, and the chief inspectors of that service were responsible only for checking their work and the presence of gambiae in the houses. Thus there was an independent check on conditions in each zone given by the reports of these two distinct groups, attacking the same problem from different angles. A further indirect check on the final results of antilarval work, and a direct check on the work of the disinsectization squads, were furnished by the adult capture squads which at monthly intervals visited every house in the infested area and made captures with the hand-spray gun and umbrella technique.

FIGS. 37 and 38.—Zone marker and roadside flag to guide supervisors checking work.

In addition to this routine counterchecking of results, each doctor was responsible for all the activities in his post and for inspecting it personally in so far as possible, and for checking it through especially trained efficient larvae searchers, who worked in different zones as he might indicate.

Attached to the division headquarters there were also especially trained men working directly under the director of the division who sent them at any time into any post to check on all phases of the work. These men also made special surveys wherever gambiae was discovered for the first time to determine the extent of the area infested, and made independent reports on worked areas which were being declared free of gambiae.

The chart on page 98 shows the organization of the Service during the period of its maximum activity.

DEVELOPMENT OF PROGRAM

Initial Difficulties

The Malaria Service of the Northeast encountered many difficulties and made little apparent progress during the early months of its existence. The relatively large area would have been much easier to cover had it been an island, unable to expand daily as did the gambiae infested area. Unduly rapid development of an administrative program is always uneconomical but the threat of farther spread of gambiae justified the attempt to cover the area as rapidly as possible.

While personnel was being selected and trained, gambiae was progressing in its march into previously clean areas. The 1938 surveys of gambiae distribution were dry season surveys and definite information was lacking regarding longevity of gambiae eggs, of possible estivation of adults, and the comparative extent of gambiae breeding in wet and dry seasons. These surveys had given a rough idea of the distribution of gambiae at the time they were made, but no one knew to what extent gambiae had been able to take advantage of later favorable opportunities to spread into contiguous regions.

The fact that the Malaria Service entered the field at the beginning of the rainy season was a great handicap. Malaria was

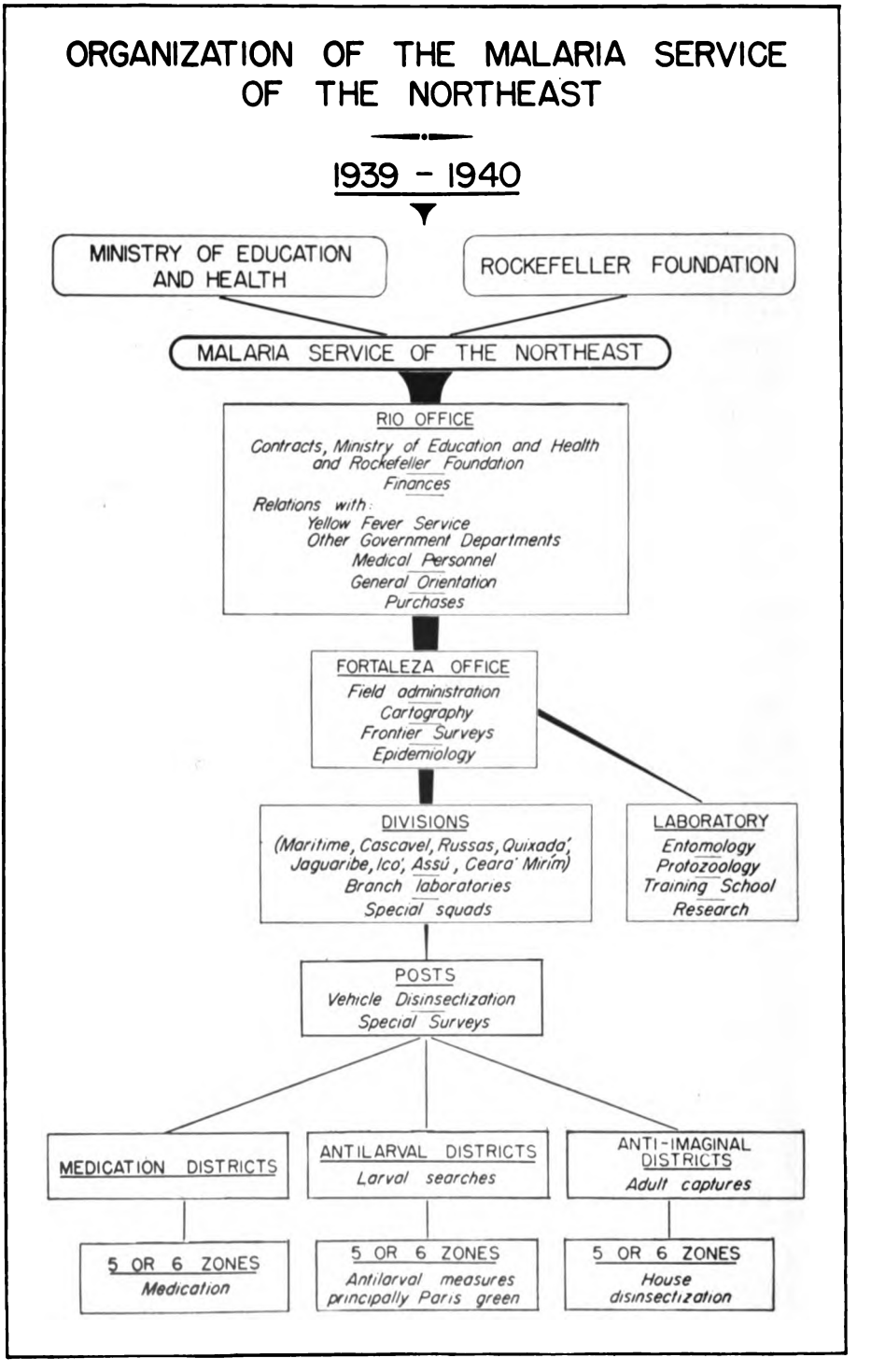


FIG. 39.

epidemic once again, as in the previous year, and humanitarian considerations forced organization of a treatment campaign at a time when administrative energy should have been concentrated on developing and applying methods of gambiae control. Malaria also constituted a serious problem for the Service in its effect on the health of the personnel. Food was difficult to obtain in many areas, since malaria had reduced production during the preceding season. Transportation away from the main highways is always slow in the rainy season. Mapping was difficult and the assignment of definite areas to be worked by individual inspectors impossible. Checking of results was uncertain and there could be no assurance that all parts of a region were being worked. The great expanse of water during the rainy season caused a false impression of the necessity for drainage and led to the digging of useless ditches, later abandoned. The multiplication of potential foci during the rainy season also made it imperative to double the number of men employed for Paris green distribution and larval searches at a time when well-trained personnel was at a premium.

The personnel question was a serious one, and the absorption of the staff of the Antimalaria Service with its seven doctors and hundreds of employees, in the face of the transfer of many men from the Yellow Fever Service to key positions in the new organization, created certain problems which could have been avoided had the Malaria Service of the Northeast started from the ground up. The personnel from the Yellow Fever Service was well trained in the technique for eradication of *Aedes aegypti* but had had no experience in working with anopheles, whereas the personnel of the Antimalaria Service, trained as malariologists, was considering the gambiae program as a malaria, rather than as a species eradication campaign. The selection and training of the thousands of men needed was in itself no small task, and the fact that it was first necessary to instruct the doctors and chief inspectors before they in turn could train the subordinate personnel created serious delays. The legal requirement of a certificate of at least one year's military training for employment by any agency using federal funds, could rarely be fulfilled by men in the back country and prevented the Service from rapidly acquiring the large number of workers needed until after special dispensation from this requirement was granted for certain types of workers.

The greatest handicap in the beginning, however, was the complete lack of a definite concrete technique which could be guaranteed to eradicate gambiae. Although it was known that the gambiae imago is highly susceptible to pyrethrum sprays and that Paris green is an effective larvicide for this species, no practical system had ever been worked out for the eradication of gambiae and the new Service began operations without a definite preformulated plan. This rendered it inexpedient to order supplies at the beginning of the campaign before their utility had been demonstrated in the field. Under these circumstances the interval which elapsed before material could be received from Rio de Janeiro or from abroad was at times a serious factor in retarding the development of the campaign.

First Six Months of 1939

In spite of the many difficulties, a great deal of important work was done during the first six months of 1939.

Surveys of gambiae distribution were made which showed the continued spread of this species in Ceará up the Jaguaribe and its tributaries and along the coast toward Fortaleza, while in Rio Grande do Norte the extension of infestation in the Apodí and Assú rivers was found to be greater than anticipated. Gambiae seemed to take advantage of the rainy season, spreading far and wide. In the Banabuiú River, an affluent of the Jaguaribe, gambiae was found in June 120 kilometers above the point which earlier in the year had been considered as the last outpost of infestation. Scores of such unexpected findings contributed to the uneasiness of mind felt by those responsible for the antigambiae campaign.

Antimalaria treatment was given to 114,000 persons, a field staff of 2,500 men (May) was mobilized, rough maps of areas to be worked were prepared, vehicle disinsectization for prevention of the transportation of gambiae to clean areas was begun, and the Central Laboratory was installed at Aracatí. Administratively, the infested area of Ceará fell into three divisions, Russas, Quixadá, and Icó, and that of Rio Grande do Norte into two, Ceará Mirím and Assú.

Much was learned about the gambiae mosquito and the advan-

tages and disadvantages of various antilarval measures in the campaign against this species. During the first four months of the year, 87 per cent of the antilarval work consisted of filling in and oiling, while Paris green accounted for only 5 per cent. By June, however, the advantages of the simplest methods of Paris green application had been demonstrated and from that month on, this larvicide became the mainstay of the antilarval work.

In spite of everything, however, no results of the general attack on gambiae, which could be given statistical presentation, were apparent at the end of June 1939. Those responsible for the orientation of the antigambiae program carefully nourished rays of hope originating from the apparent eradication of gambiae from the coastal village of Caiçara in May, from the labor camp at Lima Campos in the Iguatú area in June, and from a stretch of highway between Russas and Fortaleza, to bolster up the decision to ask for additional resources with which to expand the Service to a point where all infested areas could be covered. During the first half of the year the Malaria Service of the Northeast had spent much more than the proportional part of the year's budget, without covering all of the infested area with antimosquito measures. The central, heavily infested, lower Jaguaribe valley was repeatedly sacrificed through the withdrawal of men for the protection of the frontiers where gambiae was still spreading. In June, before additional funds for the year were assured, some 250 men working in this lower valley were laid off to guaranty funds for the payment of salaries in the important frontier areas until the end of the year. An appeal was made for additional funds and before the end of June the Brazilian Government had agreed to increase its contribution by 2,000 contos (about $100,000 U.S.) in spite of the fact that the only concrete result which could be claimed for the Service was the demonstrable reduction in mortality from malaria due largely to the treatment campaign. This was especially striking at Russas where the antimosquito measures had not yet been adequately organized (Table 28).

Second Six Months of 1939

During the second semester of 1939 gambiae made slight gains in territory in the Assú, Apodí, and Jaguaribe river valleys and a

jump of fifty kilometers took place along the coast from the mouth of the Pirangí to Caponga in the direction of Fortaleza. As each new frontier focus was discovered, small armies of workers were sent in to cope with the situation.

In addition to the routine frontier surveys, special reconnaissance trips were made to many localities, well beyond the known infested area. These led as far afield as the States of Paraíba, Piauí, and Maranhão. Fortunately, although it was feared that gambiae might have been transported to some distant point and there established itself, no evidence of its spread beyond the States of Ceará and Rio Grande do Norte was ever found.

The three divisions into which the infested area in Ceará had originally been divided proved too large to be handled satisfactorily and in the second semester of 1939 two more divisions were organized, Cascavel and Jaguaribe. It was early in this semester that the Maritime Division, already referred to in the section on frontier defense, was installed.

An important development during this period was the inauguration of routine house disinsectization, at first in a few and later in all infested areas. Wholesale disinsectization was not instituted until December and so its full effect was not felt until the following year. Although antilarval measures alone had brought about the apparent complete elimination of *A. gambiae* in several of the most heavily infested districts, it was hoped that the introduction of anti-imaginal measures would speed up the process.

In the second semester of 1939 the Malaria Service continued to overspend its budget. It was felt that large amounts expended at the outset for encircling the known infested area and for a concerted effort to push gambiae back toward the lower Jaguaribe would, in the long run, be profitable by preventing extensions to well-watered areas which might render later eradication many times more difficult and expensive.

In addition, therefore, to the 2,000 contos increase already agreed to by the government during the first semester, 3,000 contos ($150,000 U.S.) more was requested. In asking for the additional appropriation, three facts were stressed: first, that the budget as originally planned had not included funds for medication and that up to August 1939 almost eight hundred contos' worth

($40,000 U.S.) of drugs had been bought and distributed in the infested areas; second, that although gambiae had made no long-distance hops it had nevertheless gotten within twenty-five kilometers of Fortaleza and was also traveling south, threatening the well-watered-area around Crato from which extension to the São Francisco River valley might be possible; and third, that in June 250 employees had been released, not because they were not urgently needed elsewhere, but because of the rapidly dwindling budget. The additional 3,000 contos was granted, bringing the total sum appropriated for gambiae work by the Brazilian Federal Government in 1939 to 10,000 contos or some $500,000 U.S.

By the end of 1939 the Malaria Service of the Northeast could begin to feel some real optimism. The places cleaned during the first six months had not become reinfested and before the end of the year, gambiae was no longer being found at Caponga, on the coast; at Forquilha, Bom Successo, and Cariús on the upper Jaguaribe (Ceará); and at Assú, Lake Piató, and São Gonçalo (Rio Grande do Norte). Before these gains could be considered definite, however, the disturbing question, as to what extent the success of gambiae elimination from these areas was due to the effect of the dry season had still to be answered. Only after the rains of 1940 began would a satisfactory solution be forthcoming.

That local observers did not share this optimism, however, is revealed by the following quotation from a speech made by P. A. Sampaio, in September 1939, in Pará:

> It is therefore undeniable that all the barriers which have been raised against it, all the prophylactic measures taken to exterminate or detain it, have been ineffective.
>
> And as gambiae's field of action becomes wider, more difficult becomes the fight against it, less effective the prophylactic measures, more expensive the campaign and more uncertain its success.
>
> The Rockefeller Foundation began in February with a government credit of five thousand contos, later increased to seven thousand contos, and a grant from The Rockefeller Foundation of two thousand contos.
>
> At the present time it would be premature to express any opinion as to the results and efficiency of the Service organized by the representatives of The Rockefeller Foundation.

First Six Months of 1940

Based not only on apparent results already obtained but also on the existence of a trained staff, the year began with some optimism of a proven technique and of what was confidently thought to be an adequate budget. The budget for the first six months of 1940 amounted to 12,500 contos ($625,000 U.S.): 10,000 contos ($500,000 U.S.) from Brazilian Government funds and 2,500 contos ($125,000 U.S.) from The Rockefeller Foundation.

The rainy season set in earlier than usual in 1940, substantial rains having fallen in many places as early as the preceding December. In the first week of 1940 the special frontier squad discovered a gambiae focus near Quixará on the Cariús River. This represented a jump of about fifty kilometers from the focus at Cariús, which had been discovered and cleared up in the last half of the preceding year, and directly threatened Crato, less than fifty kilometers away on a passable highway. Large numbers of combat workers were at once dispatched and at the end of four weeks, gambiae had apparently been exterminated, as it did not reappear in this zone. No other new areas of infestation were found during the semester.

But in spite of this spearhead of invasion up the Jaguaribe valley, gambiae was giving way rapidly throughout the infested regions in the face of the onslaught with Paris green and insecticide. Reports from every division showed that gambiae-free areas were becoming more and more extensive, even during the rainy season. On the other hand, however, gambiae increased rapidly in Gracismões and Cumbe, the two districts where in order to permit the study of gambiae under natural conditions no control measures were being carried out.

In his paper before the Pan American Sanitary Conference in Washington, D.C., in May 1940, E. Chagas, who directed the work of the Division for Studies on Endemic Diseases in Gracismões, said:

> With the continuation of the dry season up to January 1940 the adult density (in the comparison area of Gracismões) went gradually down again, with a rise in October due to unexpected rains in this month. In January, February, and March, 1940, the adult density became very high so that in April, in the second half of the month we already had a very high index

of adults. The rise appeared sooner this year than in 1939 and this fact coincides with the period of rainfall which was also earlier this year.

Concurrently with the reported decrease in the incidence of gambiae there was a greatly diminished demand for antimalaria treatment during the first half of 1940, and in many areas prophylactic administration of drugs to the personnel of the Malaria Service was suspended.

At the end of 1939 and in January 1940, respectively, Drs. G. K. Strode and L. W. Hackett visited the Malaria Service of the Northeast. In view of the apparent absence of gambiae in certain sections, each independently suggested that the validity of this disappearance be tested by abandoning all control measures and giving gambiae freedom to reappear.[1] However, it was not until mid-April 1940 that this challenge to gambiae was put into effect. The area chosen for the original test was a large part of the Salgado valley in the Icó Division, at one time heavily infested but which had apparently been clean for some three months. Control measures were suspended and elaborate precautions were taken to guard against any unrecognized persistence of gambiae by instituting both larval searches and house captures of adults in the areas abandoned. The training of inspectors to recognize adult gambiae is fairly easy, but training to recognize larvae is more difficult. It was decided to trust entirely to microscopic examination for the identification of larvae and therefore collections of larvae from all anopheles foci found were taken to the division laboratory for classification. No evidence of persistence of infestation or of reinfestation by gambiae in cleaned areas in which control measures had been suspended was found. The men released consequently from these areas were sent to the divisions on the lower Jaguaribe, which had never been adequately manned; the work of the Russas Division, the only one without a frontier, was especially affected by this measure.

[1] Dr. Hackett's experience in Durazzo, Albania (Hackett, *et al.*, 1938), made him especially emphatic on this point. There, after a whole summer without a single *A. maculipennis* var. *elutus* in an area where the campaign against that mosquito was being waged through salinification of its only breeding place, intensive production of *elutus* followed when failure to keep open the salt water intake made its former breeding place again suitable.

With the decision to suspend gambiae control in Icó, orders were given simultaneously to inaugurate control measures in the study areas at Cumbe, near Aracatí, and at Gracismões, near Russas, for it was felt that gambiae now constituted a threat to the surrounding countryside there. That this danger did exist was confirmed by house captures which produced 2,202 adult gambiae in 49 houses at Cumbe and 5,825 gambiae in 47 of the 58 buildings in Gracismões. These figures are conclusive evidence that the season was a highly favorable one for the production of gambiae and that the reduction of density of this species at other points noted during the rainy season itself was due to control measures.

Gambiae's failure to reappear following the suspension of control activities was most heartening and not less so was the demonstration that the Malaria Service of the Northeast now possessed a technique whereby gambiae could be pushed back and driven out even during the rainy season. By the end of the first semester of 1940 it was apparent to all that the final liquidation of gambiae in the known infested areas was but a matter of months, and the campaign became an exciting race between the personnel of different divisions to see who could finish with gambiae first.

Second Semester of 1940

The optimism of the first semester was reflected in a voluntary reduction of 20 per cent in the Service budget.

The retreat of gambiae continued rapidly during the second semester and the routine was followed of abandoning disinsectization in an area shortly after it failed to show either larvae or adults and of suspending the application of Paris green after a period of three months of freedom from gambiae (Fig. 40). As the frontier areas became clean, more and more men were released and were then concentrated in the remaining dirty areas.

The monthly maps of gambiae distribution in 1940 show clearly the way in which the cleaning of one section was followed rapidly by the cleaning of others. During the month of May, the Russas Division, the last of the known infested sections to be cleaned, had 226 dirty points; during June, 126; during July, 103; and during August, only 18, some of which were completely cleaned

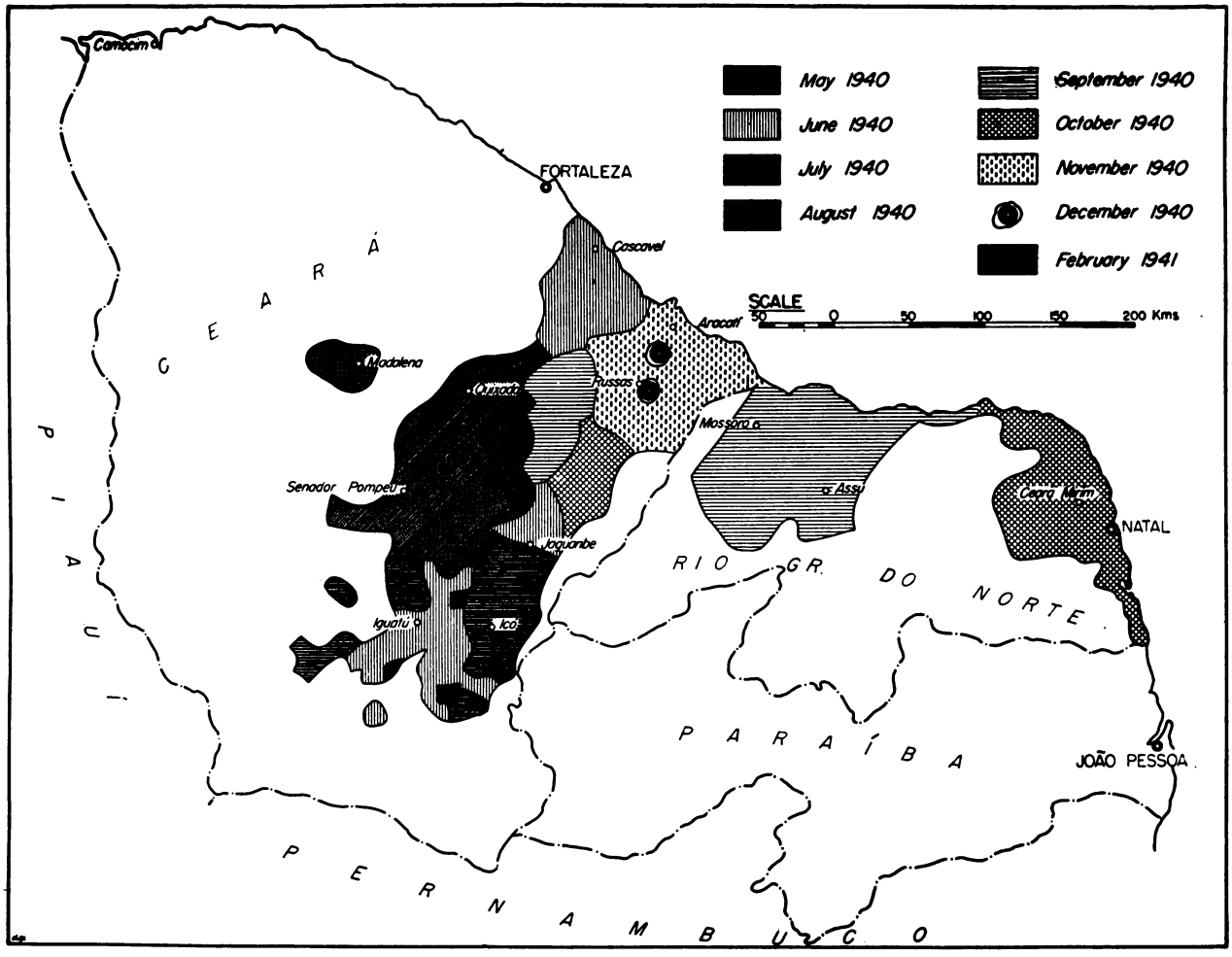


FIG. 40.—Suspension of antilarval measures.

up before the end of the month. No gambiae was found in this division after September 9.

Once the Aracatí sector of the Russas Division was proven to be clean, the laboratory colony of *A. gambiae* in Aracatí was regarded as a potential source of reinfestation and was therefore killed off on August 31.

On September 7, Brazil's Independence Day, a luncheon was given to members of the staff of the Malaria Service in Fortaleza to celebrate the virtual extinction of gambiae in the Northeast. Some outside observers thought this premature but the staff knew from personal experience that control measures had been developed to the point where the trained personnel of the Malaria Service was capable of cleaning immediately any new area of infestation which might appear. The opportunity to test this optimistic attitude arose a few weeks later when a previously unknown pocket of gambiae infestation was uncovered in October at Madalena beyond the Quixadá Division, some sixty kilometers from Quixadá. The last autochthonous gambiae found in Brazil was collected November 9, the last larva November 14, 1940.

Another indication of the efficacy of the control measures was the decline in the number of individuals seeking treatment at the various posts. By September 1, 1940, there were not enough cases of malaria to justify keeping special employees to treat the few cases which did appear, and treatment was suspended throughout the whole area.

The year 1940 ended with all control measures against gambiae, including both Paris green and insecticide, suspended except in the small area at Madalena. Complete optimism existed regarding the absence of gambiae from the controlled areas, but considerable reservation was made as to complete species eradication because of the possibility of gambiae's having escaped to more distant regions.

CHOICE OF ANTIMOSQUITO MEASURES

Preliminary Plans and Recommendations

Although gambiae had been in Brazil for some eight years and a successful campaign had been waged against it in Natal, the

Malaria Service of the Northeast began its activities in 1939 with no very clear-cut program for the eradication of gambiae from Brazil other than to rely on Paris green as much as possible, study the possibility of using disinsectization of houses by spray insecticide, and work from the periphery of the infested area toward the center. Before discussing the choice of methods actually used by the Service, it may be worthwhile to present some interesting extracts from the preliminary suggestions for an *Anopheles gambiae* program made by Shannon following the 1938 survey. These suggestions are interesting for their points both of similarity and dissimilarity with the program as finally carried out. In considering them it must be remembered that they were based on dry season observations.

It appears impossible for gambiae ever to extend its breeding range up the river beds much beyond its present limits. . . .

Plan of attack

(1) If it is possible to begin before the wet season . . . control should be started along its upper limits in all the infested stream courses. This would delay and perhaps prevent epidemics in a number of localities during the next rainy season. Filling in all exposed caçimbas and pools should suffice.

(2) The cultivated seepage and subsurface water areas at Alto da Cheia (Ceará) and São Gonçalo (Rio Grande do Norte) are special problems. The most effective control would be ditching to give quick drainage of the water. This, however, would probably prevent cultivation in these areas until after gambiae has been exterminated. Meanwhile, the people living here would probably have to be cared for. Paris greening, on the other hand, may be all that is required, with some alterations in the present system of cultivation.

(3) River and lake beds. It is too late in the dry season to succeed in accomplishing the results of value in the main river courses, especially in the Jaguaribe. Even though an attempt were made to destroy all breeding places (probably quite an impossible task owing to the very extensive area to be covered and difficulty of transporting men, etc.) and an attempt made to flit all houses (equally impossible) there would doubtlessly remain sufficient adults capable of producing sufficient numbers of new individuals to bring about fresh epidemics even during an exceptionally light rainy season.

The best which can be done at present would be to start propaganda among the people living along these sections of the river in the hopes that they would succeed to a greater extent in reducing gambiae than we could with the number of men we would be able to put on the job during the short period

of the dry season which remains. This education should also be of value during the next dry season.

Perhaps the best thing which can be done toward helping in the antigambiae work in these breeding areas would be to prohibit the growing of sweet potatoes in all of the infested valleys and to enforce the covering of all types of caçimbas and water holes with the possible exception of those at which animals drink.

Further, to stock all water bodies wherever possible with gambusia.

(4) Paris green. As gambiae larvae have only been found in very small, usually shallow pools, it would appear that the filling in of such would be far more effective than using Paris green. This applies to dry season conditions.

During the wet season Paris green may prove very important in certain localities but to attempt to cover the entire breeding area at this time would probably prove prohibitive.

The filling in of all unprotected water holes, with the possible exception of those used for animals, should prove more effective than Paris green. It will be necessary to do this once a week.

. . . *Breeding during a heavy rainy season* . . . would doubtlessly be so intensive and extensive it would be useless to attempt to check it. All that could be done probably would be to flit adults in the houses, distribute drugs, and attempt to prevent its spread to Fortaleza and also south from the Potengí valley.

. . . *Breeding during a light rainy season* . . . Paris greening by hand may prove highly successful providing the roads are open to transportation.

Survey Methods

Surveys to determine the presence and intensity of gambiae infestation in areas under control, as well as in areas contiguous to known infested regions, were made by searching for larvae and/or capturing imagoes. At times one, at times the other, and sometimes both methods were used.

Gambiae breeding during the dry season is so definitely limited to certain types of water collections that failure to find larvae in these collections may be regarded as very good evidence of its absence from the region. Likewise, gambiae is so highly domestic in Northeast Brazil that failure to capture adults in houses is also good presumptive evidence that it is not present in the community.

Search for Larvae

Search for larvae was carried out by:

special squads making the initial survey of an area;

the chief inspector checking the efficiency of the application of Paris green (Fig. 41);

special independent mobile squads checking existing conditions against reports of local staff; and

the sentinel service maintained in previously infested areas after control measures had been discontinued, following the disappearance of gambiae.

Sample collections of larvae were made and forwarded to the field laboratory from all anopheles foci found, and all larvae classified as gambiae were sent to the Central Laboratory for confirmation.

Contrary to the practice in many malaria services, the inspector

FIG. 41.—Chief inspector searching for larvae.

responsible for the application of larvicide wasted no time searching for larvae. His only responsibility was to treat his area with Paris green so thoroughly that gambiae larvae could not be found by the chief inspector checking his work.

Imago Captures

House capture of adult gambiae was carried out by:

special squads making the initial survey of an area, including a census of houses and population;

routine adult capture squads which checked the disinsectization work at weekly, monthly, or even quarterly intervals, according to circumstances;

special independent mobile squads checking local conditions against reports;

sentinel service maintained in previously infested areas after this service had suspended the larva search referred to above.

The capture methods employed were:

Hand capture tube with syringe suction bulb.—When gambiae is plentiful, the manual capture tube is fairly satisfactory in spite of the fact that its success depends on the inspector's ability to see the mosquito against the background of mud walls, thatch roofs, and other objects offering little or no contrast. Hand capture was found to be difficult and time consuming and was early abandoned in favor of the use of spray insecticide.

Spray-insecticide-umbrella method (Barber and Rice).—This was modified by the use of a square umbrella[1] so made as to fit into corners, under furniture, and along the line of the wall, the insecticide being sprayed directly over the umbrella (Figs. 42-47). This method was found to be especially rapid and economical for making surveys[2] of gambiae density in areas where antilarval measures were not being applied. It was used especially

[1] Modified by Ferreira and Soper (Figs. 42-47).

[2] In one of the Malaria Service of the Northeast's first field tests five inspectors caught fifty-one *A. gambiae* in a house at Caiçara in five minutes' time with hand-capture tubes. A rapid four-minute application of spray with umbrella capture immediately after in the same house produced ninety-one gambiae. An additional sixty-seven gambiae were recovered from some four meters of floor surface where they had missed the umbrella.

FIG. 42.—Folding square umbrella.

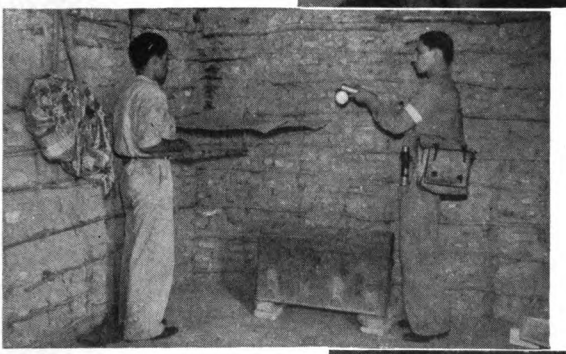


FIG. 43.—Spraying over umbrella.

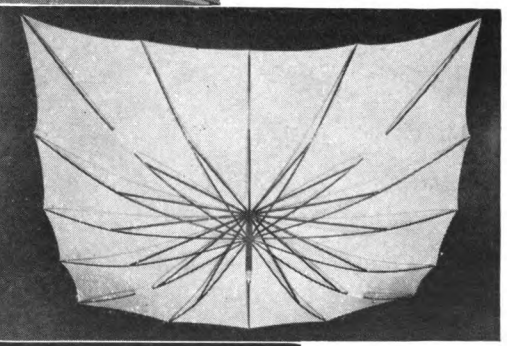


FIG. 44.—Square umbrella, open, seen from below.

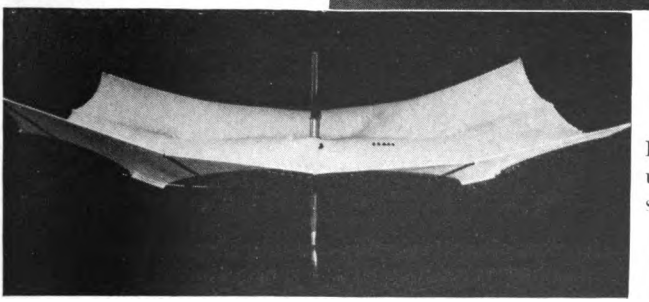


FIG. 45.—Square umbrella, open, seen from above.

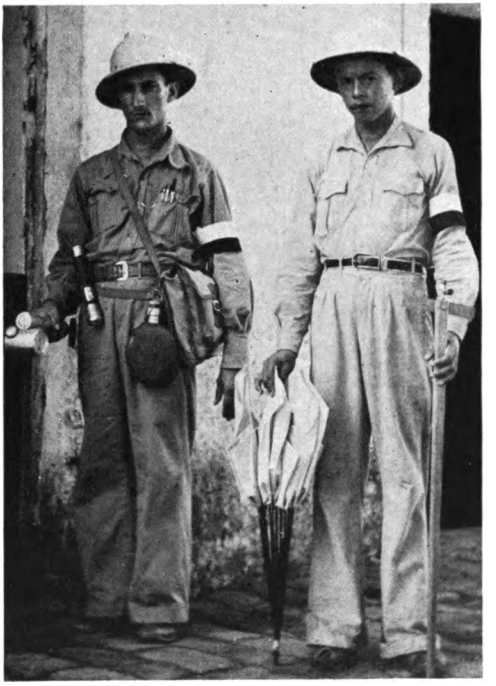


FIG. 46.—Capture team with folded umbrella.

for pre- and postcampaign surveys. In the absence of antilarval measures, experience showed that satisfactory surveys could be based on captures limited to the sleeping quarters,[1] which are the preferred resting place of the gambiae mosquito. The ordinary hand spray gun[2] is more satisfactory for use with the umbrella than the compressed air pump, since its range is generally great enough even to reach mosquitoes resting on the ridgepole of the low houses of the region, while the current of air produced is not strong enough to blow them clear away from the umbrella.

Spraying of insecticide with compressed air pump and collection from floor of the mosquitoes knocked down.—Doors and windows are closed and rooms sprayed one at a time, beginning with the darkest sleeping room and finishing with the kitchen,

[1] Hammocks are universally used in this region; the term bedroom is not appropriate.

[2] The recent 1942 development of small cylinders charged with pyrethrum in Freon or other substance which has high vapor pressure at ordinary temperatures promises to make this method a practical one-man job.

following which the mosquitoes are collected in the same order. Since many of the homes in the rural areas and at the periphery of the towns and villages in Northeast Brazil have floors of earth or brick, on both of which it is difficult to see mosquitoes, the inspectors using the power spray pumps must be carefully trained to search rapidly every square meter of floor surface, as well as behind pictures and furniture, on shelves, tables, and wherever else dead mosquitoes may fall. The greatest density of fallen anopheles is generally encountered in a narrow zone some thirty-five centimeters wide next to the wall.

In areas under control this method was, as a rule, used to make monthly surveys of distribution of the species and to check on the increase or decrease in density in infested areas. For these surveys it was important to know whether or not a single gambiae mosquito was present in any given house and, therefore, it was customary to spray and search the entire house.

In comparing the relative merits of the insecticide-umbrella method of capture and the insecticide-floor-searching method for use in other campaigns, it should be pointed out that the laboratory favors the use of the floor-searching over the umbrella method because the umbrella tends to become soaked with insecticide, which spoils for detailed study the mosquitoes which fall into it.

FIG. 47.—Mosquito capture team demonstrating use of square umbrella.

Gambiae caught in the umbrella could be distinguished from local anopheles, but local anopheles so caught often could not be distinguished one from another.

After identification and registry by the inspector, all mosquitoes captured in a given house were sent in a small pasteboard pill-box to the field laboratory for confirmation of classification, and eventually to the Central Laboratory for final identification. The use of separate containers for the mosquitoes from each house made it possible, if any were identified as gambiae, for the inspector to seek out and destroy the responsible foci in the house noted.

Attention should be called to the fact that the only duty of the squads responsible for routine disinsectization was to spray the houses with insecticide so thoroughly that all gambiae present were destroyed. No time was lost searching for and counting the number of mosquitoes present either before or after the application of the insecticide.

Importance of Capture Data

In Natal, South Africa (Park Ross), experience had shown that the capture of adults in the kraals revealed the beginning of the annual seasonal increase of gambiae ten to fourteen days before such increase was apparent from the search for larvae, and in Brazil the house capture of adult gambiae early came to occupy a most important place in determining the infestation of an area, in evaluating the efficiency of different antigambiae measures, and, later, in checking on the careful application of the measures adopted. The capture of adults is used as an independent yardstick to gauge the results of control measures and is especially useful in areas which have been under control for some time, where any gambiae found represents either a slip in technique or a failure to cover the entire breeding area.

The work with gambiae tends to confirm the results of antiaegypti work which had shown adult captures to be a more sensitive indicator of the presence of highly domestic mosquitoes in a given community than is the search for larval foci. Only those who have worked with such highly domestic mosquitoes as *Aedes aegypti* and *Anopheles gambiae* are able to appreciate the close

check of the breeding conditions in an area which can be made through the capture of adults in the houses.

Control Methods

Of all the measures devised for the control of mosquitoes only two, Paris green to kill larvae and pyrethrum spray insecticide to kill adults, were employed on a large scale by the Service.

Antilarval Measures

The so-called naturalistic methods of control were not attempted; the attack on gambiae was frontal and direct.

Drainage in general was of little use in the gambiae campaign and swamp drainage was found to be unnecessary.

Flooding land with sea water was used only on the lower Potengí River in Natal, in the area of original gambiae infestation.

Filling was used for the elimination of certain small collections of water which could be filled easily with near-by soil. New borrow pits, new water holes, and after the floods of the rainy reason subsided, new marginal pools were constantly being formed, so that the number to be filled was always great.

Marginal filling and regulation were used at times to make all parts of pools and streams accessible to fish, but the artificial *distribution of fish* was not attempted.

Oil was used as an emergency larvicide, during the first three or four months of work, since supplies were at hand and some of the available workers were familiar with its use.

Paris green application to all foci was practically the only antilarval measure employed after the first few months. The method of application varied according to the season:

wet method, a mixture of water and a stock emulsion of Paris green and kerosene (Barber, Rice, and Mandekos, 1936), used during the rainy season when water was easily obtainable;

moist method, the stock emulsion mentioned above and moistened pebbles, wet sand, or even earth (Griffitts 1927; Barber, Rice, and Mandekos, 1936), used during the transition period between dry and wet season;

dry method, dust, dry sand, or dry earth, used during the dry season when practically no water could be found.

FIG. 48.—Mosquito capture team between visits.

Other measures vs. Paris green.—The failure to use many of the methods in the armamentarium of the modern malariologist was due to the urgency of the situation, to the peculiar local conditions which made some of them useless, and to the fact that measures designed for anopheles reduction may not be equally advantageous in eradication campaigns.

Drainage requires technical planning and supervision, is slow, expensive, and in regions subject to annual rainy season flooding must be renewed each year. Where the program is one of local malaria control for a limited population in a given area, drainage may often be used to advantage, but in a campaign for species eradication, there is no profit in moving water from one point to another, unless by so doing it can be eliminated as a possible source of breeding at the point of delivery.

The artificial distribution of fish was not employed in spite of the fact that the fish hatcheries of the Department of Agriculture offered unlimited supplies of local minnows which had proven very effective against *Aedes aegypti* larvae. The majority of gambiae foci during the rainy season were found away from the river beds and were too temporary to offer living conditions for minnows;

dry season foci, on the contrary, were mostly in the river beds, where fish occurred naturally, it being necessary only to rectify the margins to permit their access to the entire water surface.

Oil has many disadvantages in a species eradication campaign, among which may be cited its cost, the difficulty of distribution to workers in the field, and the rendering of essential water supplies unfit for use. After the application of Paris green was systematized, oil was used only as a disciplinary measure to force compliance with the protection of water holes against infestation.

One of the great advantages of Paris green, as used by the Malaria Service of the Northeast, is that at no season of the year is it necessary to spend money on the transportation of diluent for the larvicide. It is easy for the inspector to carry the necessary Paris green or stock emulsion and to find a suitable diluent at his place of work. The difference in distribution cost alone gives Paris green a tremendous advantage over oil as a larvicide for species eradication campaigns in which all of the infested areas must be worked.

The application of Paris green presented some difficulties at first, but soon came to be the only antilarval measure employed throughout the infested area. Both the low price of labor and the type of water collection preferred by gambiae made the hand application of Paris green the method of choice, although it may well be less effective against other anopheles which do not, as does gambiae, prefer open shallow pools without vegetation and only the margins of large collections of water.

Paris green as used by the Malaria Service of the Northeast.— Paris green as a larvicide has been known to Brazilian workers for many years, but it had never been used on a large scale and many minor but important details of technique had to be learned before its use was adapted to the conditions of Northeast Brazil. During the first months of 1939 there were no stocks of suitable Paris green available except a small order which had been placed by the Antimalaria Service and no one in Brazil was familiar with the wet method of Paris green application. As the Malaria Service of the Northeast began to work during the rainy season when road dust was not obtainable, preliminary plans were made to use dust from one of the cement factories, but analysis of transportation costs showed this to be impracticable.

FIG. 49.—Knapsack pressure spray pump for Paris green and water.

In the early months of the use of Paris green in the antigambiae campaign, the larvicide was applied on a weekly cycle, since gambiae may develop to the imago within six days after oviposition. Later, as peripheral areas were cleaned, freeing personnel for the final drive on the infested central areas, semiweekly treatment was adopted because, under field conditions, a given application of Paris green may fail to kill 100 per cent of the larvae present.

The first attempt to use the wet method of Paris green application gave unsatisfactory results, probably because distribution was by common garden sprinklers. When Excelsior[1] horticultural pressure pumps equipped with mechanical agitator paddles became available (Fig. 49), highly satisfactory results were obtained. Laboratory tests showed that constant agitation of the larvicide during spraying is imperative, but that the addition of egg albumen or

[1] Hasenclever & Cia., Av. Rio Branco, 69/77, Rio de Janeiro. Manufactured in São Paulo, Brazil.

castor oil to effect an even distribution of the Paris green (Barber, Rice, and Mandekos, 1936) is unnecessary. The addition of egg albumen did improve the suspension of Paris green in water, but it also rendered it less buoyant and therefore less effective, as large quantities immediately sank when spread upon water. It was also found that Paris green containing special floating agents is unsatisfactory as it tends to froth and be blown to one side of pools being treated. Nine types of Paris green with particles varying in size from two to twenty-five micra were tested. Field and laboratory observations indicated that the two- to three-micra Airfloat Paris green[1] was by far the best for antigambiae work.

The wet method finally adopted required the inspector to carry to the field a small amount of a stock emulsion in the proportion of one gram of Paris green to two cubic centimeters of kerosene or Diesel oil. At the site of application, one part of this emulsion was mixed with 100 parts of water taken from the foci to be treated and the resultant liquid was applied with knapsack pressure spray pumps. The only serious drawback to this method of application is that it necessitates carrying a pump, weighing some twenty pounds, from place to place.

The moist method proved its value during the transition from the dry to the wet season, when dry earth is not yet available and when pools with sufficient water to fill the knapsack pump are scarce. It is quite effective especially for gambiae larvae which have been observed to feed at the bottom of pools as well as at the surface but requires very careful application since the Paris green-kerosene-wet sand mixture, broadcast by hand, is not spread by the wind as is the Paris green-dust mixture.

The favorite method of the Malaria Service of the Northeast for the application of Paris green, however, was that in which the dry mixture was used. It was less messy and, aided by the wind, a given area could be covered more quickly than with the kerosene or oil mixture. Arrived at the place of application the inspector scooped up (Fig. 50) approximately one kilogram of dry earth, dust, or fine gravel and mixed this thoroughly with ten grams of Paris green, repeating the operation until five kilograms had been mixed.

[1] Chipman Chemical Company, Inc., Bound Brook, New Jersey.

FIGS. 50 and 51.—Mixing and broadcasting Paris green and dust.

FIG. 52.—Antilarval inspector equipped for action.

For this work, the inspector only needed to carry around with him (Fig. 52) a small supply of Paris green, a standard measure for ten grams, a pail with a mark indicating the approximate level reached by five kilograms of earth, and a grocer's scoop for collecting dust. In most divisions the mixture was dispersed by hand (Fig. 51), but in others the scoop was also used (Fig. 27), in which case, the inspector needed some practice to acquire the proper knack of distributing the mixture evenly. But it was worth the effort as it diminished the risk to the operator of chronic arsenic poisoning, which was uncomfortably frequent during the early months of the use of the larvicide by inexperienced men (Table 16).

Such poisoning constituted the chief disadvantage of Paris green, as used in the antigambiae campaign. The most common manifestations were acneform dermatitis on the forearms and hands, vesicles on the upper lip and nasal alae, ulcers of the scrotum, with occasional secondary pyogenic infections, and epistaxis. Efforts to avoid this field hazard included insistence on frequent baths and clean fingernails. The men were trained to take every pre-

TABLE 16

PARIS GREEN MORBIDITY AMONG FIELD PERSONNEL

1939, 1940, and 1941

PERIOD	KILOGRAMS OF PARIS GREEN USED	CASES OF ARSENIC POISONING	CASES PER 1,000 KILOGRAMS PARIS GREEN
1939			
First semester	7,642	121	15.8
Second semester	76,270	154	2.0
Total	83,912	275	3.3
1940			
First quarter	34,692	112	3.2
Second quarter	52,873	74	1.4
Third quarter	67,684	105	1.5
Fourth quarter	21,536	22	1.0
Total	176,785	313	1.8
1941			
First quarter	595	0	0

caution in mixing and spreading the Paris green-dust mixture, but the veering gusty winds of the river beds made it difficult. Gradually the inspectors learned to work with minimal contact of skin and mucous membranes with the dust, with gratifying results; those who reacted severely and persistently were transferred from the antilarval to some other branch of the Service, when all signs of poisoning disappeared rapidly.

Official complaints were received from county authorities and private individuals in a score of localities to the effect that Paris green was killing cattle, goats, sheep, and chickens. Even abortions in domestic stock were attributed to the Paris green applied in the watering holes. A careful consideration of these complaints showed that some of the abortions were due to brucellosis, which had not hitherto been reported in Ceará. Agglutination tests on selected sera showed that brucella infection occurred in the human population, in dairy cows, and in goats (Causey and Causey, 1942).

Fortunately popular opinion did not attribute any human ailments to Paris green, and only six accidents were reported during the application of some 260 tons in Northeast Brazil. Paris green was the lethal agent for two suicides; it was swallowed by three children, two of whom recovered; and an overzealous inspector, who also eventually recovered, suffered severely from a public demonstration of the nontoxicity of Paris green in which he added a goodly portion of it to his beer.

Anti-imaginal Methods

Screening, which looms so large in some antimalaria campaigns, had no place in the program of the Malaria Service of the Northeast. The houses of the region worked could have been made mosquito proof only with great difficulty; screening material was very expensive and, even had it been possible to screen on a large scale, this measure would not have had an appreciable influence in checking the spread of the species nor in eradicating it. As a matter of individual protection employees of the Malaria Service working in infested zones were supplied with special mosquito nets adapted to the hammocks in which they slept.

Destruction of adult mosquitoes.—Historical. The attack on adult mosquitoes for the reduction of mosquito-borne disease is

not new but dates from the first antimosquito campaigns organized after it was demonstrated that malaria and yellow fever are transmitted by mosquitoes. Fumigation was an integral part of the campaigns of Gorgas and Oswaldo Cruz for the eradication of yellow fever from Havana and Rio de Janeiro and, although he later abandoned the idea, Gorgas at first considered this measure to have been a major factor in his success at Havana.

Although Carlos Chagas (1906 and 1908) early advanced the theory that malaria is a domiciliary disease, acquired in the house and transmitted by house-frequenting mosquitoes, it is surprising that until recent years no large-scale attempts were made to control malaria through the destruction of adult mosquitoes, in contrast with the extensive and enthusiastic attempts to destroy adult mosquitoes in the control of yellow fever. But even in the case of yellow fever, adult destruction methods were aimed at the infected mosquito in an attempt to get rid of the disease and were not part of a program to eradicate the guilty species.

The firse large-scale use of spray insecticide instead of fumigation for the destruction of infected mosquitoes is believed to have been made in the anti-aegypti campaign during the 1928-29 outbreak of yellow fever in Rio de Janeiro. Dr. Emygdio de Mattos found the spray insecticide very efficient, but its application by hand pumps impracticable in military barracks and other large buildings. An appeal for ideas was made to the local representative of the manufacturer of one of the more popular commercial spray insecticides, who suggested the use of the paint spray pistol operated by compressed air. This led to the development of equipment with which houses totaling 183,243 floors were disinsectized in Rio de Janeiro during the years of 1928-29 (Fraga 1930).

In 1933-34, the weekly spraying of houses and huts by hand pumps was introduced for the control of malaria in Natal, South Africa, where *A. gambiae* and *A. funestus* are the principal vectors. Park Ross (1936) reported that the systematic use of spray insecticide was invariably followed by a sharp reduction in the number of cases of malaria in huts and barracks and by the disappearance of epidemic conditions.

One of us (F.L.S.) had an opportunity to visit South Africa in 1935 and see at first hand the work done in Natal and Zululand

under the direction of Park Ross, and was duly impressed. Three years later Park Ross reported (Personal communication, 1938):

> You will be interested to hear that we have prevented epidemic malaria in Natal and Zululand for five years now by hut spraying. We have seldom had such heavy breeding as during the past two years and had a sprinkling of cases all over the country; but only a sprinkling, and in every case we stamped it out by spraying before there was any semblance of even a minor outbreak.

The results in Africa led to the testing of adult destruction as a means of malaria control in other regions (Covell, Mulligan, and Afridi, 1938; Russell and Knipe, 1939).

In India the use of spray insecticide apparently caused a great reduction in malaria transmission, without noticeably affecting the house density of the principal vector *A. culicifacies,* which is not essentially a domestic species. In other words, the results were obtained by an attack on the parasite in the infected mosquito in the house rather than by an attack on the mosquito species itself.

Technique of spray disinsectization used in Brazil. The results obtained with spraying in South Africa were correlated with a great reduction in the number of gambiae in the huts, which suggested that spray insecticide might be useful in the campaign about to be undertaken in Brazil for the eradication of this highly domestic mosquito.

Spray insecticide was used by the Malaria Service of the Northeast:

to reduce the density of adult gambiae and, as a result, the possibility of its spread from infested to clean areas by infiltration or by transportation;

to destroy adult gambiae being carried by train, car, truck, boat, and plane;

to shorten the period of continued egg laying, after larval control was begun, by killing off a large number of the adults which otherwise would have oviposited; and, at the same time,

to reduce the incidence of malaria by preventing the mosquitoes which emerged, in spite of antilarval measures, from developing infectivity.

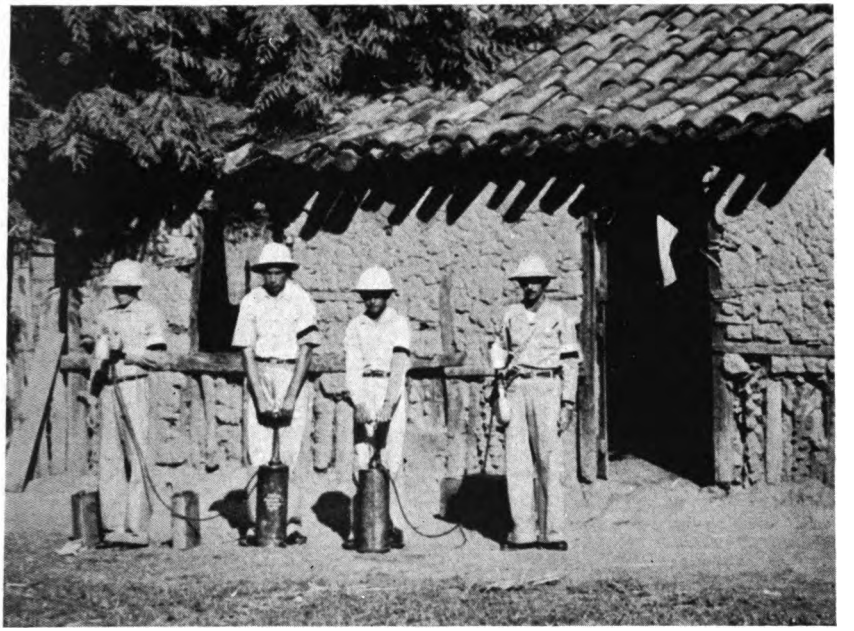


FIG. 53.—Rural spraying squad.

Various experiments were made before the insecticide mixture finally employed was evolved. Kerosene and various types of Diesel oil were tested, and the Diesel oil marketed under the trade name of Combustol proved to be a more toxic vehicle than other oils and kerosene. Even when Combustol was applied alone in the routine way, many mosquitoes in cages placed in the houses sprayed were later found dead. With kerosene alone no mosquitoes were killed. Combustol had the disadvantage, however, of leaving a thin oily film on furniture and other household articles.

Since many of the houses sprayed had open kitchen fires, carbon tetrachloride was added to the insecticide to reduce inflammability. In the proportions used, the mixture would flare when sprayed into an open flame, but no accidents ever occurred from this source. The addition of more carbon tetrachloride would have greatly reduced the buoyancy of the atomized spray in the air. An attempt to use water as a vehicle for pyrethrum extract was unsuccessful, the atomized fog settling quickly to the floor.

The spray insecticide used was in most cases composed of five parts of a pyrethrum concentrate 1-20 (trade name Pyrocide 20), which contains 2.0 grams of pyrethrins in each 10 cc. of the pyrethrum concentrate, ten parts of carbon tetrachloride, added for its fire-preventing as well as insecticidal properties, and eighty-five parts of kerosene or Diesel oil.

The equipment used consisted of a spray pistol of the DeVilbiss type requiring a tank for compressed air with at least fifteen pounds pressure to the square inch for satisfactory operation. Most of the work throughout the rural areas was done with small portable hand-operated tanks, whereas gasoline engine powered tanks, capable of giving thirty-five to forty pounds pressure for several spray pistols operating simultaneously, were used in the towns and at the larger disinsectization posts for vehicles.

In the rural areas the disinsectization squad, consisting of one inspector and three laborers, equipped with two hand-powered pressure pumps and two spray pistols (Fig. 53), made the rounds weekly, spraying all buildings and outhouses in the zone assigned to it. All doors and windows were closed and, with two laborers

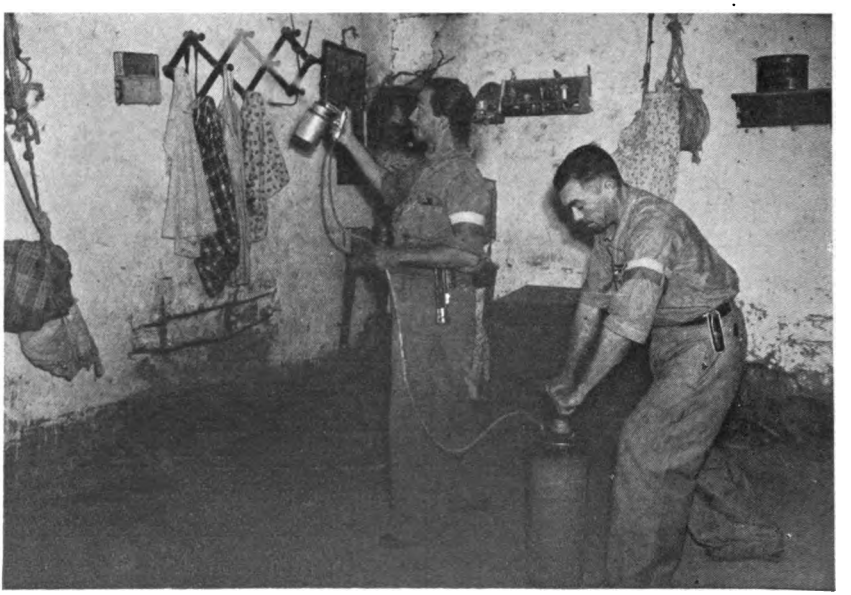


FIG. 54.—Spraying interior of house.

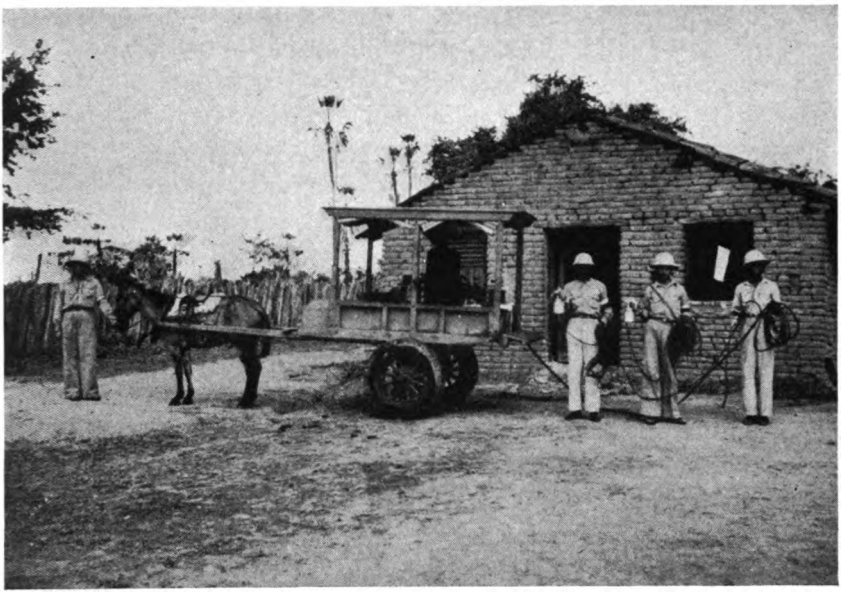


FIG. 55.—Urban spraying squad.

manning the pumps and the inspector and one laborer each operating a pistol (Fig. 54), the rooms were sprayed one at a time until a cloud of spray was visible from the roof to the floor. Instructions were left with the family to keep the house closed for ten minutes after spraying. No attempt was made on routine disinsectization to count or collect the mosquitoes killed but a careful record was kept of the houses sprayed, the time spent in each house, and the amount of insecticide used. To facilitate checking the work of the squad the inspector noted the date of the spraying and the hour of his arrival and departure on a form which was posted in each house.

In the towns, mule-drawn carts were used to carry the gasoline motor equipment with a number of spray pistols attached to the compressed air lines, from house to house (Fig. 55). With such equipment, disinsectization of the larger houses and buildings of the towns is relatively easy.

No attempt was made to seal the houses before spraying. This would have been an impossible task in the thatch-roofed and mud-walled houses of the region worked. Spraying has an advantage

over fumigation, in that the spray is a cloud of minute droplets which do not disappear by expansion and dilution as do gases such as sulphur dioxide. Rooms need not be hermetically sealed to force contact of disinfectant with mosquito, but simply closed for a few minutes.

After the decision was made to disinfect houses as a control measure, weekly spraying of all houses in infested areas was organized as rapidly as the necessary personnel and equipment became available. Preference was always given to the organization of disinsectization work in the peripheral and frontier areas, so that only relatively late in the campaign, after the periphery was clean, were the heavily infested central areas treated. After the adult capture and larval breeding indices of an area were both reported as zero, weekly disinsectization of houses was discontinued.

Disinsectization of trains, trucks, passenger cars, boats, and planes was regularly carried out at certain key points of departure from the infested areas or immediately after arrival in clean districts. Provision was made for twenty-four hour service at the more important points. The same pyrethrum extract mixture used for the disinsectization of houses was employed, except that for use in planes the proportions of pyrethrum and of carbon tetrachloride were both doubled.

DEFENSE OF FRONTIERS

Delimitation of the Infested Area

When the Malaria Service of the Northeast took over the work at the Antimalaria Service in January 1939, the latter organization had been in the field just over two months and had not had time to make a detailed survey of the extent of gambiae breeding along the principal rivers in the States of Ceará and Rio Grande do Norte. The information gathered by Shannon and Andrade at the end of 1938 became rapidly outdated as gambiae continued its advance up the river valleys in the rainy season of 1939. During the first half of the year many local surveys, starting at the highest known points of gambiae infestation in 1938, were made to determine how far this advance had gone. In November 1938 the spearhead of infestation had been found at a point on the Salgado River

some five kilometers south of Icó. Three months later, the Malaria Service of the Northeast reported gambiae twenty-three kilometers farther up the valley and by May it had reached Ouro Branco, another ten kilometers farther.

Without going into lengthy details it is difficult to convey an adequate impression of the meticulous methods employed in the surveys whose principal objective was to delimit the frontiers of the gambiae-infested area. Larvae searches and adult captures were the methods employed, but the dogged persistence of the investigators who, in spite of continuously negative findings, examined all the water collections and houses along the river courses for thirty or forty kilometers, must be taken into account as the principal factor in determining the success of the surveys. The best men of the Service were always entrusted with these missions.

In addition to direct surveys, other sources of information as to gambiae breeding were the reports of the Yellow Fever Service whose aegypti capture squads occasionally found adult gambiae, and the reports of unwonted outbreaks of malaria. Thus, on June 20, 1939, the Yellow Fever Service reported finding gambiae at Senador Pompeu, where Shannon had failed to find it late in 1938. This early notice permitted prompt measures to be taken at Senador

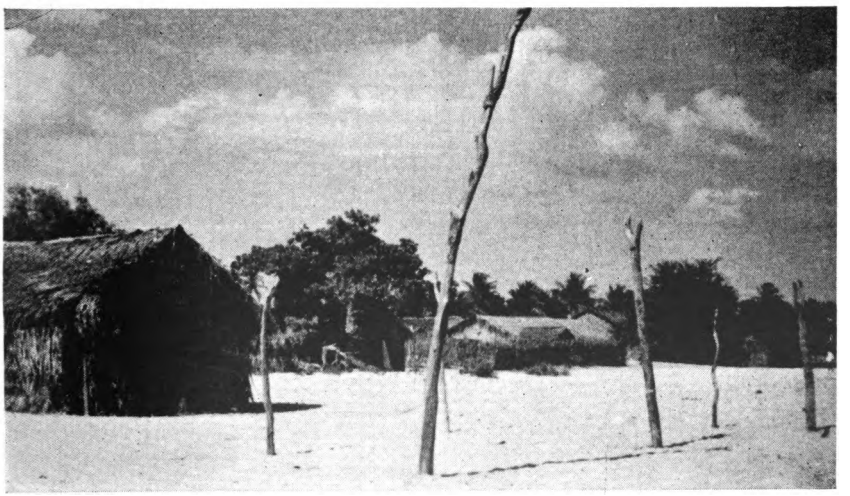


FIG. 56.—Caiçara. Poles for hammocks used by the people to escape from the mosquitoes which infest the dwellings.

Pompeu which, located as it is on the River Banabuiú and on the main line of the railroad linking Fortaleza and Crato, might well have become an important distributing center of this species.

Reports of severe outbreaks of malaria were always investigated by the Service, especially when they referred to epidemics occurring where malaria had never been known before. Field investigation of such reports several times revealed unknown extensions of the infested area. Among others, the towns of Caiçara (Fig. 56) and Areias, on the coast of Ceará, east of the mouth of the Jaguaribe River, which had been surveyed by Shannon four months previously with negative results, were shown to be heavily infested when an outbreak of malaria was investigated in March 1939.

As soon as a new frontier area was found to be infested, house disinsectization and Paris green squads were thrown in and vehicle fumigation organized, to curb farther extension. No effort was spared to get gambiae breeding on the periphery under control as quickly as possible, and during the first half of 1939, before sufficient numbers of trained men became available, the central part of the gambiae-infested area of Ceará was repeatedly bled of its personnel to help establish an effective cordon around the frontier.

Antigambiae Work in Frontier Areas

Following the surveys which demarcated the infested area as accurately as possible, the prevention of the spread of gambiae to adjacent clean territory was attempted by disinsectizing all motor vehicles, boats, trains, and planes leaving the infested areas (Fig. 57), and by treating the zone beyond the infested frontier with antilarval and anti-imaginal measures as if actually infested. This treated frontier band varied in width from eight to twenty-five miles, depending upon the abundance of potential breeding places.

After neither larvae nor adults of gambiae had been found during a minimal period of three months, the disinsectization of houses and the application of Paris green were discontinued to permit any hidden breeding to develop to a point where it would be readily recognized through the search for larvae and the capture of adults. Eventually, after a longer period in which no gambiae was found, the cycle of house captures was lengthened and the search for larvae reduced to a system of spot checking. Beyond the immediate

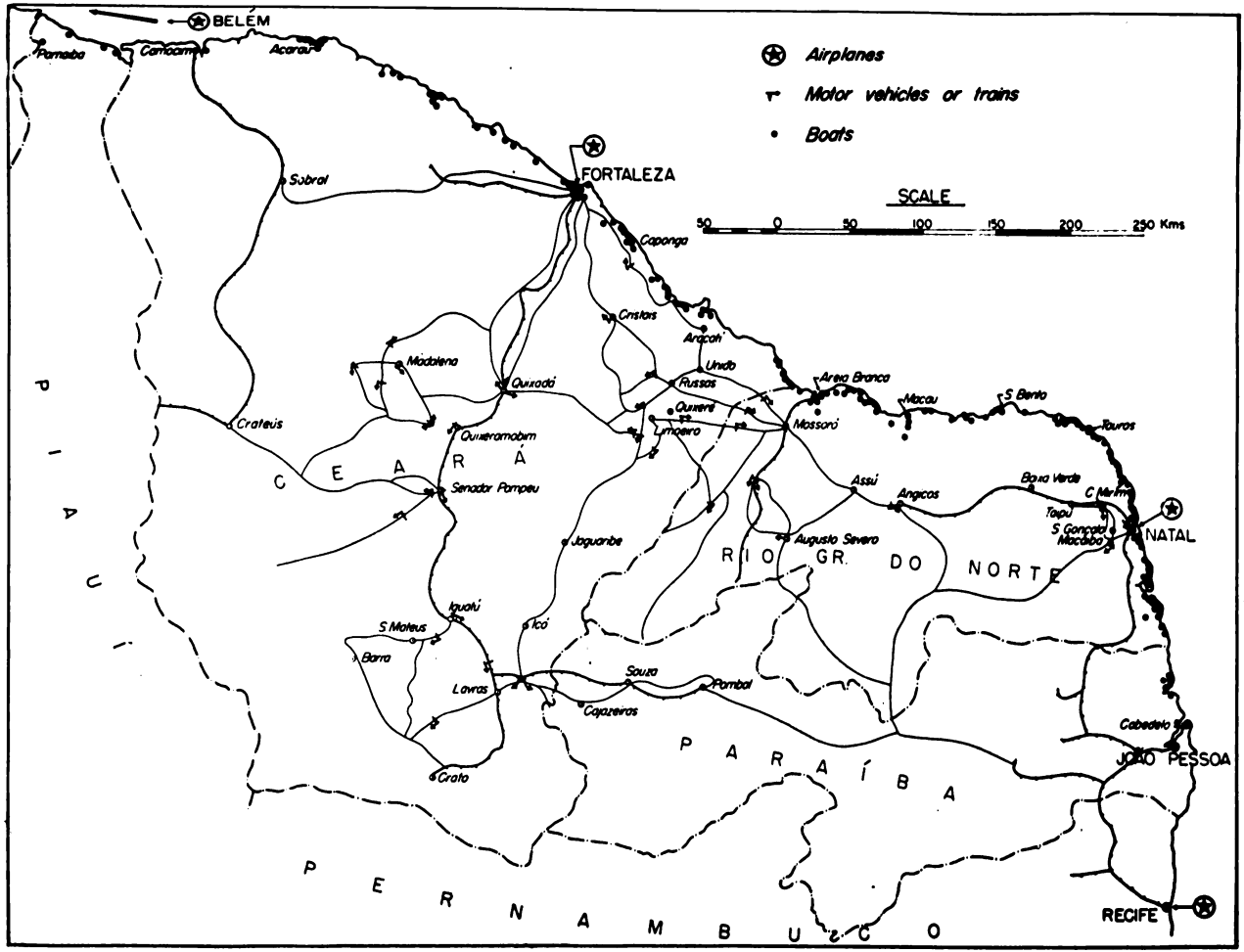


FIG. 57.—Disinsectization posts.

frontier a second wide band was searched quarterly for adult mosquitoes.

It was always borne in mind during the period when gambiae density was at its height, in 1938 and the beginning of 1939, and to a lesser extent in 1939 and in 1940 when the number of gambiae was smaller, that this mosquito might have been transported to some distant point where it could have become established. Accordingly, semiannual reconnoitering for gambiae adults and larvae was made in a third band in river basins 100 miles beyond the last gambiae frontier. These groups, searching for gambiae far from the frontier, used a modified type of survey. Based on the "negative phototropism" of the species, captures were made only in the two darkest rooms, usually the windowless sleeping quarters, of houses located near potential foci. The insecticide-square umbrella method was used and, after identification, the mosquitoes collected were sent to the Central Laboratory in appropriately labeled small pasteboard boxes. The breeding places investigated for larvae were the caçimbas, the margins of ponds and pools, and other preferred collections of water; the larvae found were sent to the laboratory for identification.

The value of surveying beyond the known frontiers was repeatedly proven. In one instance, the fishing village of Caponga, fifty kilometers beyond the gambiae territory, was found infested. This constituted an especially dangerous threat, as the village is situated at the edge of the well-watered coastal area about Fortaleza. Other extra-frontier infestations were uncovered at Barra, Cariús, Quixará, Lavras, Bom Successo, and Madalena.

Possibly the frontier work, like certain other phases of the anti-gambiae campaign, was overemphasized, but if so it was because of the known disastrous consequences of leaving unrecognized infestations in favorable areas. Beyond the immediate frontier lay watersheds leading to the northwest, west, and south, and had these become infested the complete eradication of the species from Brazil might well have become impracticable.

Disinsectization of Vehicles

The urgency of the establishment of fumigation posts for automobiles and trucks was brought home to the Malaria Service of

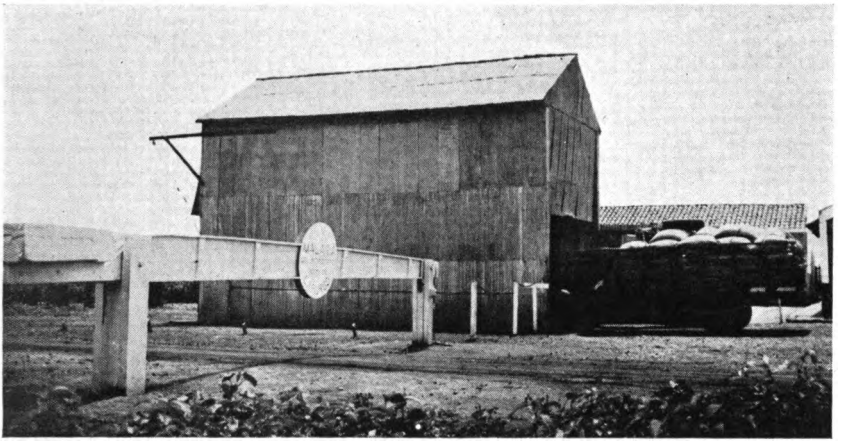


FIG. 58.—Disinsectization post for vehicles.

the Northeast in April 1939 when twelve gambiae were found at Russas in a car which had just come in from the rural districts where gambiae was plentiful. The presence of a gambiae focus in the public square at Limoeiro, though no adult gambiae could be found, was later explained after gambiae mosquitoes had been discovered in a car parked in the public square on the basis of importation by automobile.

From the heavily infested region of the lower Jaguaribe access to Fortaleza is easy and frequent as borrow pits along the main highway afford excellent breeding places for this species. Therefore, the first and most important disinsectization post (Fig. 58) set up was at Cristais, on May 14, 1939, to protect the Fortaleza area. A total of thirty-three disinsectization posts for automobiles and seven for trains were established at strategic points on all the principal roads and railroads leading from the infested area (Fig. 57). Gambiae was found six times in cars and once on a train, as may be seen in Table 17.

The disinsectization posts varied from the main highway type with gasoline motor compressors to simple road barriers where hand-powered pumps with spray pistols were used. Standard road barriers and dismountable houses for the crew (Fig. 59), portable

TABLE 17

DISINSECTIZATION OF VEHICLES AND BOATS

VEHICLES AND BOATS	1939	1940	1941
Cars and Trucks	16,201	24,935	5,557
Gambiae	4	2	0
Other anopheles	30	248	41
Other mosquitoes	57	376	461
Trains	6,168	8,972	—
Gambiae	1	0	—
Other anopheles	72	668	—
Other mosquitoes	948	1,840	—
Boats	7,307	18,983	—
Gambiae	7	0	—
Other anopheles	6	9	—
Other mosquitoes	319	664	—

by truck, were prefabricated, thus making it possible to install a fully equipped post at any desired point in a matter of hours.

The average automobile was treated by closing the windows and doors and spraying an excess of insecticide in the car and baggage compartment. After five minutes' interval the car was opened and a brief search made for dead mosquitoes, but as the contents of the car were not removed for this search, it is assumed that many dead mosquitoes were overlooked.

Trains leaving the gambiae area were routinely sprayed at their last overnight stop in the area, special attention being paid to those en route to the Fortaleza area and to the equally vulnerable Cariri valley in the Araripe plateau region.

Airplane Disinsectization

One of the greatest threats of gambiae extension throughout Brazil and of reimportation from Africa, lay in airplane transportation. At the time of the first transoceanic flights, planes did not offer good shelter for mosquitoes, but modern craft, some of which are sealed to maintain constant air pressure within, provide excellent traveling facilities for many insects. By 1939 (Whitfield 1940)

227 different species had been reported in commercial planes traveling in Africa and from South and Central America to Miami. *A. gambiae* were found in Africa on six different occasions.

Until the French and German lines were discontinued during the present war, their planes arriving at Natal and Recife from Africa were sprayed upon arrival, as were those of the Italian Lati line which carried on for the Axis powers up to the end of 1941. Careful disinsectization of Pan American Airways planes from Africa (Figs. 60, 61, 62) was instituted from the beginning of that Company's service in October 1941. Four airports are now under the constant vigilance of the plane disinsectization service: Recife, Pernambuco; Natal, Rio Grande do Norte; Fortaleza, Ceará; and Belém, Pará (Fig. 57). Table 18 gives in summary form the surprising results of insect captures on aircraft, some of which were American and British military planes, coming from the Old to the New World.

In the nine months' period, October 1941 to June 30, 1942, specimens of gambiae were recovered on seven different occasions from planes arriving in Natal from Africa: one female, apparently of the *melas* variety not previously seen in Brazil, was found on the second plane inspected after the inauguration of the Pan American African service; and six more females were recovered on January 8 and 10, on May 17 and 26, and on June 15 and 23, 1942.

Brazilian army planes making regular flights along the coast from Recife to Fortaleza and stopping at Natal, were also disin-

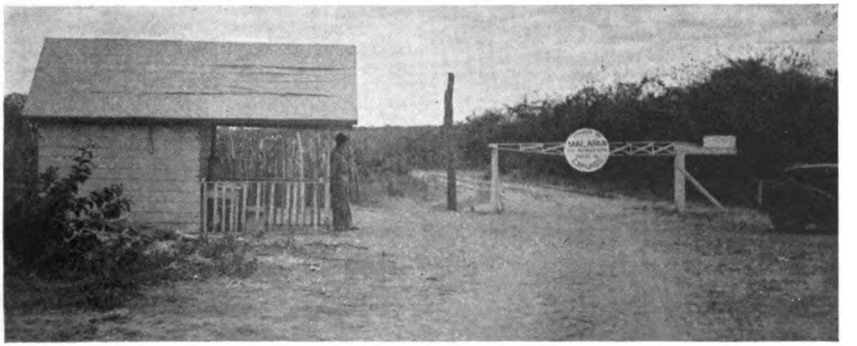


FIG. 59.—Road barrier and house for crew.

sectized. Other army planes, carrying mail through the interior, were supplied with hand spray guns and insecticide for use in case of landings in gambiae territory.

Maritime Division

A Maritime Division was organized in July 1939 to take measures for the prevention of infestation of clean ports by gambiae and

Figs. 60, 61, and 62.—Entering plane with spray gun functioning; spraying plane; and collecting insects.

TABLE 18

ARTHROPODS COLLECTED AFTER DISINSECTIZATION OF AIRPLANES ARRIVING IN BRAZIL FROM AFRICA

(Identifications Made in the Yellow Fever Research Laboratory at Rio de Janeiro for the Malaria Service of the Northeast)

ORDER FAMILY GENUS SUBGENUS	SPECIES	1941			TOTAL	FIRST QUARTER 1942			TOTAL
		PORT OF ARRIVAL				PORT OF ARRIVAL			
		Belém	Recife	Natal		Belém	Recife	Natal	
Orthoptera									
Locustidae	—	—	—	—	—	—	—	1	1
Blattidae	—	—	1	3	4	1	—	12	13
Unclassified	—	—	—	—	—	—	—	2	2
Ephemerida	—	—	—	84	84	—	—	2	2
Hemiptera									
Nabidae	—	—	—	—	—	—	—	1	1
Cimicidae	—	—	—	1	1	—	—	1	1
Unclassified	—	—	—	3	3	—	—	14	14
Dermaptera	—	—	1	2	3	—	—	5	5
Coleoptera	—	—	1	10	11	—	—	37	37
Lepidoptera	—	—	—	11	11	—	—	69	69
Diptera									
Dolichopodidae	—	—	—	—	—	—	—	5	5
Therevidae	—	—	—	—	—	—	—	1	1
Tipulidae	—	—	3	1	4	—	—	3	3
Simulidae	—	—	—	2	2	—	—	15	15
Chironomidae	—	—	—	6	6	—	—	2	2
Culicidae									
Chaoborus	—	—	—	101	101	—	—	84	84
Anopheles									
Myzomyia	gambiae	—	—	1	1	—	—	6	6
Anopheles	coustani var. Ziemanni	—	—	—	—	—	—	2	2
Uranotaenia	—	—	—	1	1	—	—	—	—
Mansonia									
Mansonia	—	—	—	1	1	—	—	—	—
Mansonioides	africanus ?	—	—	—	—	—	—	20	20
Mansonioides	—	—	—	—	—	—	—	2	2
Aedes									
Stegomyia	aegypti	—	—	1	1	—	—	—	—
Ochlerotatus	taeniorhynchus	—	—	—	—	2	—	28	30
Ochlerotatus	—	—	—	—	—	—	—	2	2
Unclassified	—	—	—	—	—	—	—	1	1
Culex									
Melanoconion	—	—	—	2	2	—	—	2	2
Culex	—	—	—	—	—	—	—	64	64
Unclassified	—	—	—	—	—	—	—	3	3
Unclassified	—	—	—	4	4	—	—	—	—
Mycetophilidae	—	—	—	3	3	—	—	5	5
Tabanidae	—	—	1	2	3	—	—	6	6
Drosophilidae	—	—	—	3	3	—	—	58	58
Diopsidae	—	—	—	2	2	—	—	1	1
Muscidae									
Glossina	pal. alis	—	—	1	1	—	—	1	1
Unclassified	—	16	99	152	267	7	—	946	953
Unclassified	—	—	—	—	—	—	—	1	1
Homoptera									
Cicadellidae	—	—	—	8	8	—	—	—	—
Trichoptera	—	—	—	—	—	—	—	1	1
Hymenoptera	—	—	—	7	7	—	—	11	11
Formicidae	—	—	—	—	—	—	—	62	62
Araneae	—	—	—	1	1	—	—	4	4
Grylhoidea	—	—	—	—	—	—	—	5	5
Ephemenoptera	—	—	—	—	—	—	—	2	2
Staphilinidae	—	—	—	—	—	—	—	1	1
Odonata	—	—	—	—	—	—	—	2	2
Micropizidae	—	—	—	—	—	—	—	1	1
Thysanura	—	—	—	—	—	—	—	1	1
Collembola	—	—	—	—	—	—	—	1	1
Total		16	106	413	535	10	—	1,493	1,503

FIG. 63.—Mosquito-proofed water casks.

to investigate ports outside the known infested area to check extensions.

Along the coast between Natal and the mouth of the Jaguaribe River lies one of the most important salt-producing sections in Brazil, and from there salt is shipped in small freight vessels to ports up and down the coast and even up the Amazon as far as Manáos. Freighters too large to dock at Fortinho, in Ceará, and Areia Branca or Macau, in Rio Grande do Norte, the largest ports between Natal and Fortaleza, remain in the open roadstead and take their cargo from lighters and small sailing vessels which go out to them. There are also many sailing vessels which ply up and down the coast collecting and delivering salt at the smaller ports as far as Fortaleza and even Recife. Furthermore, the jangada (catamaran), local type of fishing raft, is widely used along this coast, and although of no importance as a carrier of adult mosquitoes, may be considered as a potential carrier of larvae in the water containers aboard.

The measures taken by the Maritime Division, in cooperation with the maritime police and the state health authorities, included:

search for gambiae larvae and adults on all boats, including barges;

fumigation of vessels leaving ports in the infested area, whether destined to other ports along the coast or merely delivering cargo to steamers in the roadstead;

enforcement of existing regulations requiring mosquito proofing on shipboard of necessary water containers (Fig. 63). To avoid duplication of inspections, the Maritime Division of the Malaria Service of the Northeast also took charge of the anti-*Aedes aegypti* campaign aboard the ships in this area.

Close collaboration was maintained with port captains, and sailing permits were refused to ships failing to comply with mosquito-proofing regulations to the satisfaction of the Malaria Service. Permission to leave port was also conditioned on the immediately preceding disinsectization of the vessel. In all, 26,290 boats were inspected, in seven of which gambiae was found (Table 17).

Although measures for the eradication of gambiae in the infested ports were the responsibility of the regular disinsectization and Paris green squads working along the coast, the inspectors of the Maritime Division constantly made adult and larval searches in the areas under their jurisdiction and reported their findings to the Central Office, thus establishing a valuable check on the anti-gambiae measures in the important coastal districts.

At the height of the campaign, the activities of the Maritime Division extended along the coast of four states, with 169 ports and fishing villages under surveillance, of which, at one time or another, fifty-two were found infested with gambiae (Fig. 57).

CHEMICAL DEFENSE AGAINST MALARIA

Treatment of Cases

Although the first objectives of the Malaria Service of the Northeast were the prevention of the spread of gambiae and its eradication from Brazil, the malaria problem in the infested areas was so serious that it was necessary to undertake large-scale treatment of the population until such time as the reduction in the number of mosquitoes present would cause a natural disappearance of the disease. Neither funds, personnel, nor accommodations were available for hospitalization of cases and the incidence of the disease

was so high that the decision was taken to treat all cases of acute febrile disease without the formality of either clinical or microscopic diagnosis. No attempt was made to give cases a clinical or parasitic cure, nor were comparative studies made of results obtained with quinine and atabrin.

Dispensaries were opened in all principal centers in the stricken districts and drug distributors made house-to-house visits in both urban and rural districts (Fig. 64) to treat hammock-ridden cases which could not go to the dispensaries. The number of persons under treatment in each month up to September 1940, when treatments were suspended, is shown in Table 35.

The drugs used were quinine sulphate, quinine hydrocloride, and atabrin. The treatment generally consisted of seven days' administration of quinine or of five days' administration of atabrin. Injection of quinine and atabrin were reserved for very severe cases. Plasmochine was used only to a limited extent in some of the frontier areas, in an attempt to lower the gametocyte rate.

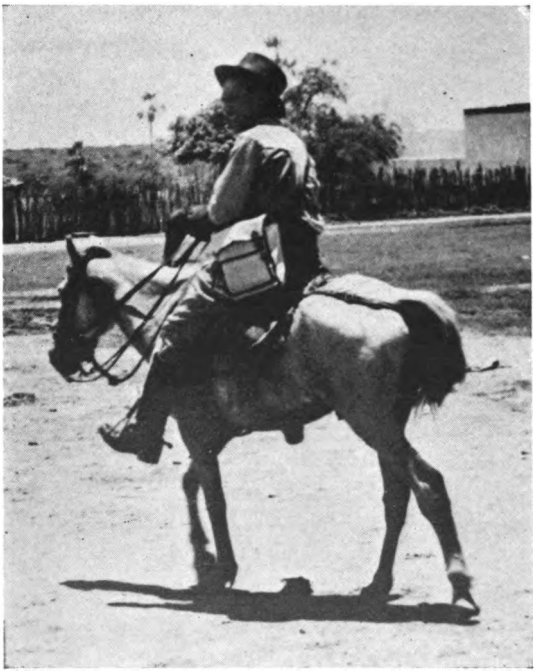


FIG. 64.—Drug distributor.

The following chart was issued to the drug distributors for their guidance in the administration of drugs:

MINISTRY OF EDUCATION AND HEALTH
MALARIA SERVICE OF THE NORTHEAST
TREATMENT CHART

AGES	QUININE (WHITE OR PINK)		ATABRIN (YELLOW)	
	Dose in Grams	Number of Tablets of 0.25 Grams	Dose in Grams	Number of Tablets of 0.10 Grams
0 to 4 years	0.25 to 0.50	1 to 2	0.10	1
5 to 12 years	0.75 to 1.00	3 to 4	0.20	2
13 years and over	1.25 to 1.50	5 to 6	0.30	3
Duration of Treatment	Seven Days		Five Days	

Precautions were taken to assure the proper use of drugs dispensed although there were many abuses, especially in the beginning. Atabrin was seldom given out for future administration since tablets of this drug were in such demand that they had an exchange cash value in many of the smaller stores of the interior. The patient was obliged to swallow the day's entire dose of small atabrin tablets in the presence of the drug distributor who could easily detect those wishing to hide the tablets between the fingers or in the hair.

In the case of quinine, since it was neither practical nor advisable for a patient to swallow as many as six quinine tablets of twenty-five centigrams at one time, there could be no certainty that a given patient really took the prescribed dosage even when only one day's supply was meted out at a time. The quinine tablets were dyed pink to distinguish them from all other quinine in Brazil and each tablet was stamped with the initials of the Service and marked "gratis," to prevent illegal sales.

PROPHYLACTIC USE OF DRUGS

Prophylactic administration of drugs was not attempted even in known heavily infested areas, except to field personnel of the Service, who received two tablets of atabrin (10 centigrams each) daily for three consecutive days followed by a rest period of six

days. Each employee was given a timetable showing the days of the year on which he must take atabrin.

The results of the prophylactic treatment of the personnel showed that the administration of antimalaria drugs will not prevent infection where much malaria and an efficient vector exist, but that it will control symptoms in the great majority of cases and permit a field force to work under otherwise impossible conditions (Table 19).

POSTGAMBIAE PROGRAM

Continued Vigilance

Although gambiae persisted in Brazil until November 1940, the postgambiae program may be said to have begun when the first decision was taken in April 1940 to discontinue all control measures in a previously infested area. Disappearance of gambiae from

TABLE 19

MALARIA MORBIDITY AMONG FIELD PERSONNEL

1939, 1940, and 1941

PERIOD	NUMBER OF MAN MONTHS	CASES OF MALARIA	MEAN MONTHLY ATTACK RATE PERCENTAGE
*1939**			
First semester	7,554	206	27.3
Second semester	10,035	127	12.6
Total	17,589	333	18.9
*1940**			
First quarter	9,531	143	15.0
Second quarter	10,736	114	10.6
Third quarter	9,549	83	8.7
Fourth quarter	5,945	25	4.2
Total	35,761	365	10.2
1941			
First quarter	4,816	10	2.1
Second quarter	4,819	13	2.7
Third quarter	2,559	2	0.8
Fourth quarter	1,889	2	1.1
Total	14,083	27	1.9

* During 1939 and early 1940 prophylactic atabrin or quinine was taken by field personnel.

the known infested region had been a continuous process beginning in May and June 1939, extending on an ever-increasing scale throughout all seasons of the year, and terminating in September 1940. Since the abandonment of control measures in areas once cleaned, begun in April 1940, had not been followed by the reappearance of the species, there was good reason to believe that gambiae had been eradicated from that region. However, the finding of gambiae in October at Madalena, near the headwaters of the Barrigas River, a full month after the last appearance of gambiae within its previously recognized range, and under conditions suggesting that it had been present at Madalena for at least some months without giving rise to any alarm, called attention to the necessity of making repeated surveys of the gambiae-infested region and of all areas which might possibly have become infested, before concluding that gambiae no longer existed in Brazil.

Plans were made for continuing the activities of the Malaria Service of the Northeast throughout the year 1941 and during the first half of 1942, that is, through two rainy seasons after the last evidence of gambiae, maintaining severe vigilance in the formerly infested territory and making far-flung surveys in other areas to ferret out any possible hidden gambiae breeding.

With the reduction in personnel and the elimination of expenditures for antimalaria drugs, for Paris green and, to a large extent, for insecticide, it was possible to work on greatly reduced budgets. While an allocation of 10,000 contos ($500,000 U.S.) was made for 1941, only 3,000 contos ($150,000 U.S.) was requested for the first six months of 1942.

Larva Collection

By discontinuing control measures in an area, any remaining foci of infestation were free to expand at will and the search for evidence of the presence of gambiae was therefore intensified. The chief inspector's weekly search for gambiae larvae, which during the control period had been carried out as a check on the efficiency of the antilarval work, was substituted by a routine monthly collection of larvae by the inspector who was responsible only for collect-

ing anopheles larvae from all foci in his zone without distinguishing species.

After Paris green application had been suspended there ensued an enormous increase in the production of native anopheles which because of their breeding habits had not been affected by the eradication methods to such an extent as had gambiae, and special facilities for the microscopic examination of the larvae collected had to be provided in the divisional laboratories. At Icó, for example, seven trained microscopists, each with his helper to prepare the material for examination, classified under supervision from twenty to twenty-five thousand larvae daily. The dates on which this routine collection of larvae was begun in various areas are shown in the map opposite.

It will be noted that the range of routine larva collections in both Rio Grande do Norte and Ceará extended far beyond the limits of the region infested with gambiae. The last pocket of gambiae infestation in Brazil, that found on the Barrigas River some sixty kilometers beyond the known limits of previous infestation, was uncovered by routine larva collection in October 1940, ten months after the last finding of the species in the Quixadá Division. Routine larva collections were not undertaken in Russas, in Ceará Mirím, and in part of the Jaguaribe Division because of the decision to utilize the capture of adult mosquitoes in the search for gambiae infestations after November 1, 1940, after which date only a small number of inspectors in each division continued surveys of breeding conditions.

Adult Capture vs. Larva Collection

Gambiae breeding in a community, unrestrained by control measures, is generally easily detected either by house captures of adults or by larva collections. Theoretically, under the conditions existing in Northeast Brazil, house captures should give the most rapid results during the rainy season since foci may be washed away or diluted by floods, and larva collections the best results during the dry season when adults are few and breeding is restricted to a limited number of potential foci. In practice both methods are highly efficient and only the greater ease of administration of

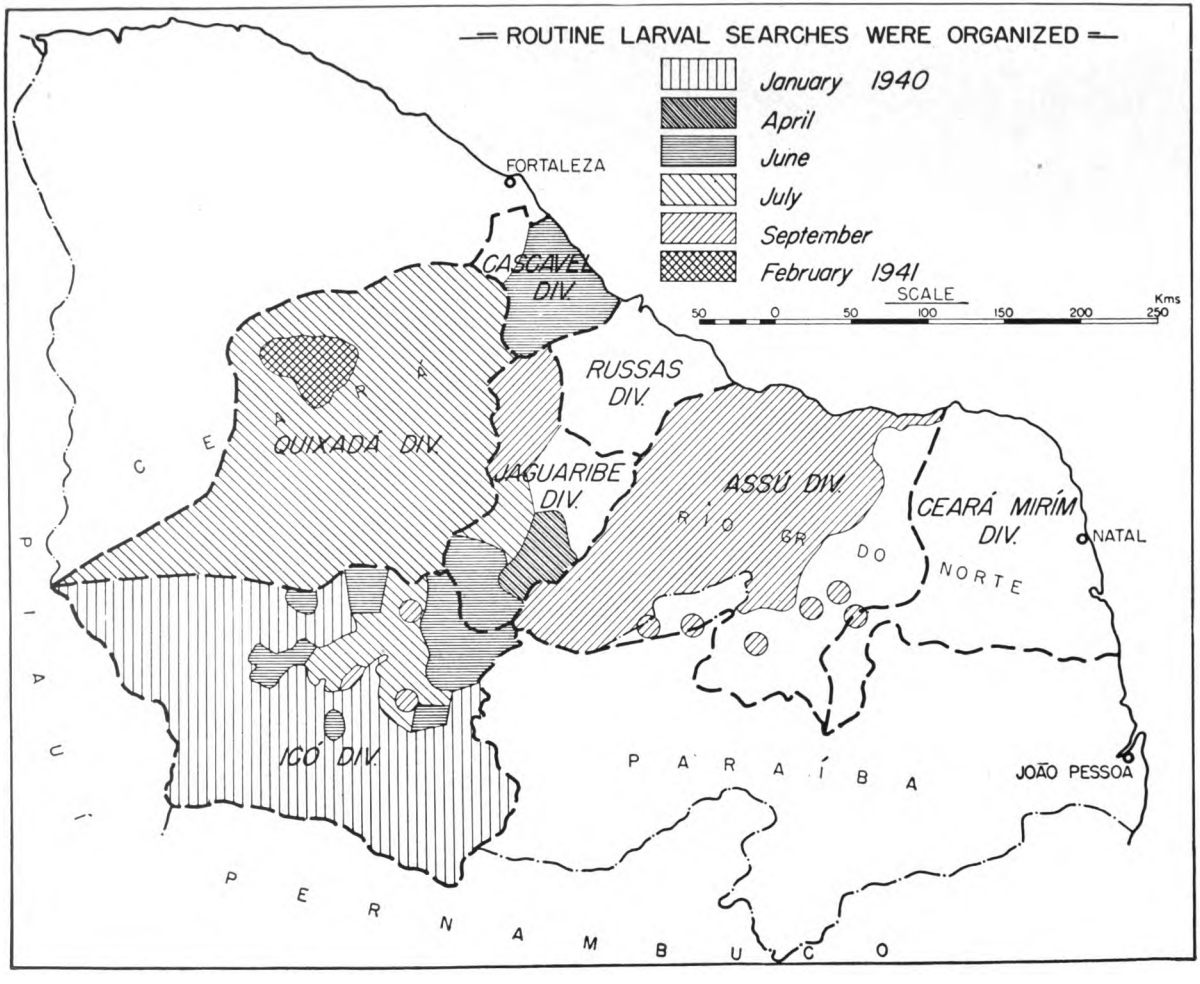


FIG. 65.—Areas covered by larva searches.

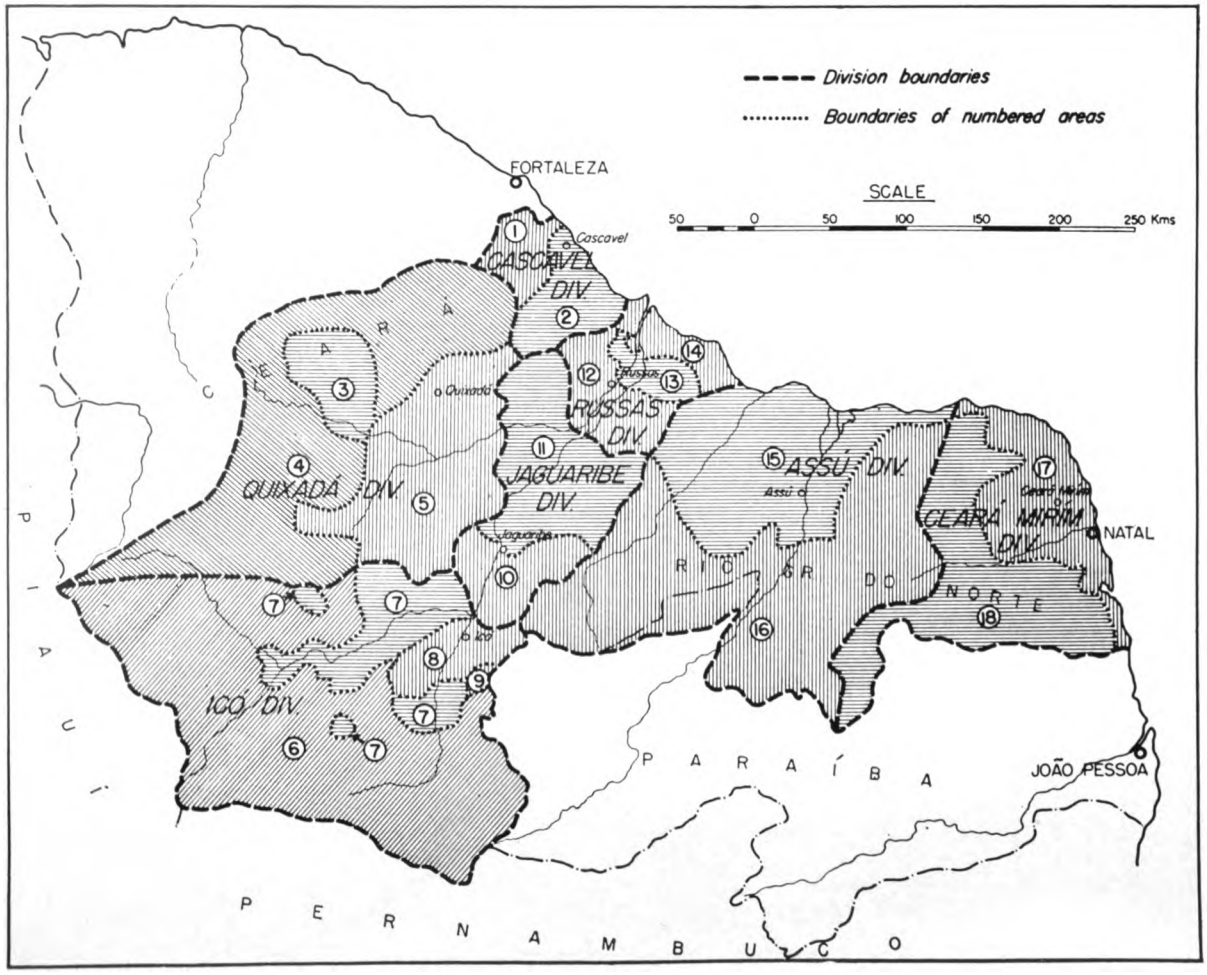


FIG. 66.—Areas covered by imago captures.

routine imago captures determined their use instead of larva collections. This depended on several factors:

the much greater domesticity of the gambiae mosquito in comparison with local native species does away with laboratory examination of large masses of negative material;

the adult gambiae is much more easily recognized in the field than is the larva;

the number of houses in an area being worked does not change from week to week and month to month as does the number of potential larva foci; this permits the organization of a regular routine capture service with the same number of men throughout the year, whereas the requirements of a larva collection service are constantly changing;

the inspector doing house captures is always in the eyes of the public; the visit record affixed to the door or wall of each house permits easy checking of his work, whereas the checking of larva collections is more difficult and uncertain.

TABLE 20

ROUTINE ADULT CAPTURE PROGRAM

(Key to Map, page 148)

SECTION	DIVISION	MONTH SERVICE BEGAN	CYCLE	MONTH CYCLE WAS EXTENDED	CYCLE EXTENDED TO	NUMBER OF INSPECTIONS MADE IN AREA UP TO 8.31.42
1	Cascavel	April 1941	Quarterly	July 1941	Semestral	2½
2		April 1941	Monthly	June 1941	Quarterly	5½
3	Quixadá	April 1941	Monthly	June 1941	Quarterly	6
4		April 1941	Quarterly	July 1941	Semestral	2½
5		October 1940	Monthly	July 1941	Quarterly	12
6	Icó	1st. semester 1941	Semestral	—	—	2½
7		June 1940	Monthly	July 1941	Quarterly	16
8		June 1940	Monthly	April 1941	Quarterly	14
9		June 1940	Monthly	March 1942	Quarterly	21½
10	Jaguaribe	January 1940	Monthly	April 1941	Quarterly	19
11		January 1940	Monthly	July 1941	Quarterly	21
12	Russas	February 1940	Monthly	July 1941	Quarterly	21
13		June 1940	Monthly	July 1941	Quarterly	16
14		March 1940	Monthly	July 1941	Quarterly	19
15	Assú	October 1940	Monthly	June 1941	Quarterly	11½
16		2nd. semester 1941	Semestral	—	—	1½
17	Ceará Mirím	November 1940	Monthly	July 1941	Quarterly	11
18		January 1941	Quarterly	July 1941	Semestral	3½

The monthly routine capture of adults was organized in some areas as early as January 1940 and was used simultaneously with routine collection of larvae in the early investigations of the areas in which control measures were first suspended. The map on page 148 and Table 20 give the pertinent data.

It will be noted that only in April 1941 was the transfer of the emphasis from larva collection to house capture complete; that the monthly cycle was used in the beginning for all of the previously infested areas and that only after June 1941, when four of the divisions had been free from recognized gambiae infestation for over a year and all seven had been free for more than six months, did the house capture cycle come to be one of three months. At this time the work was further reduced by limiting the search for mosquitoes to the sleeping quarters of inhabited houses.

Special Surveys

In addition to the routine larva collection and house capture work, organized under the direction of the different divisions, certain areas of special importance within the divisional jurisdiction and large areas which were not usually accessible to the division headquarters, were surveyed by carefully selected groups working directly under the control of the Central Office at Fortaleza. The areas covered by these special squads, which were responsible for searching for both larvae and adults, are shown with dates of surveys in the map opposite. In addition, special survey squads composed of the pick of the field workers were at times sent on expeditions into all the states along the Northeast coast line from Maranhão to Alagôas, making investigations of unusual outbreaks of malaria and examining the most likely places for gambiae infestation.

In January 1941 a reward of 100$000 ($5 U.S.) was offered to any employee who could find a gambiae focus anywhere in Brazil, and though later doubled this reward was never claimed. On September 17, twenty-seven gambiae larvae were found in material said to have been collected June 26 and 27, 1941, at Maranguape and Pacatuba, both close to Fortaleza, Ceará. Investigation revealed

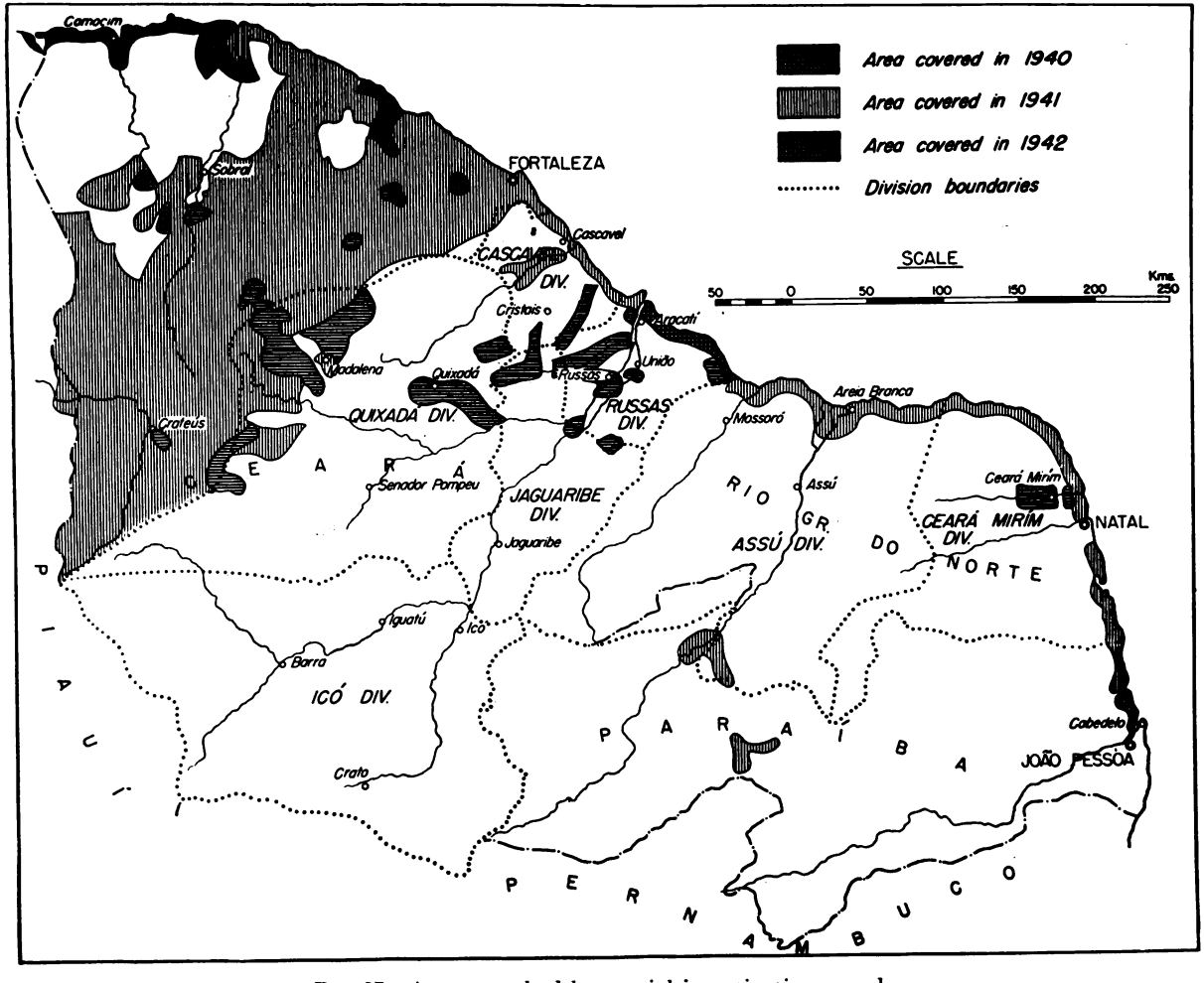


FIG. 67.—Areas searched by special investigation squads.

apparent substitution of old material which had been issued months before for demonstration purposes.

Fortunately, in spite of a year of ceaseless search, not a single native gambiae was found in Brazil during 1941.

Prevention of Infestation from Africa

In October 1940 when the number of transatlantic planes was greatly reduced, only one or two arriving in Recife monthly, the responsibility for their disinsectization was entrusted to the Yellow Fever Service, to whom subordinate personnel of the Malaria Service was loaned for work in Recife and Belém. A year later the Malaria Service of the Northeast reassumed full responsibility for plane disinsectization and reopened stations at Natal and Fortaleza to prevent the reimportation of gambiae by civil or military planes which began using these ports as American terminals for transatlantic flights. The list of insects collected during 1941 and the first quarter 1942 has been given in Table 18.

Special Studies

During 1941 special studies were made on the applicability of eradication methods to mosquitoes other than gambiae: one study was on the possibility of eradicating *Aedes aegypti* in rural areas by the monthly applications of antilarval and disinsectization measures; the other, on the possibility of eradicating local species of anopheles in a limited area. Taking advantage of the necessity of surveying a large area of Northeast Brazil for the presence of gambiae, extensive material was collected for making a more thorough study of Brazilian anopheles than had ever previously been possible. These special studies will be reported elsewhere (Causey).

Postgambiae Decline of Malaria

A close watch was kept during 1941 for gambiae-transmitted malaria but no suspicious outbreaks were noted. The hemoscopic survey made by the epidemiological section shows that the heavy parasitic rates of 1939, which were greatly reduced in 1940, had almost disappeared in 1941 in both urban and rural districts of all of the divisions.

Activities of 1942

During the last six months of the Malaria Service of the Northeast, activities were continued on a reduced scale, a skeleton organization being maintained throughout the entire region. Many loose ends were gathered up including the completion of surveys previously planned, the completion of air maps of a large area, the preparation of reports, and an edition of the manual of the Yellow Fever Service.[1]

Continued Surveys

During 1942 surveys of distant outlying areas were continued in the search for possible extensions of gambiae. Beside the more likely areas closer to previously infested territory, searches were carried out in the upper northwest corner of Ceará, along the Piauí border, and in the western half of the State of Paraíba, contiguous to the States of Ceará and Rio Grande do Norte. No gambiae were discovered in all these searches.

Air Maps

Although plans were made and work was begun on air maps in 1939, by the time the air photography was finished in 1940 but before maps were made, gambiae had disappeared from Northeast Brazil. As, however, trained personnel was already at work with specialized equipment the air photography was finished and useful working field maps were made covering an area of 10,472 square kilometers in Ceará and 2,416 square kilometers in Rio Grande do Norte. All the negatives corresponding to this area were turned over to the Military Geographic Service. In addition, the aerophotogrammetric map of the region adjacent to Natal, covering an area of 2,189 square kilometers, was completed in the first semester of 1942 and made available to government authorities.

Reports

During this same period the history of the antigambiae campaign was written, as well as reports and articles on the special activities of the Central Laboratory covering the biology of gambiae and native anopheles.

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[1] Fred L. Soper, D. Bruce Wilson, Servulo Lima, and Waldemar Sá Antunes. *The Organization of Permanent Nation-Wide Anti-Aedes Measures in Brazil.* The Rockefeller Foundation, 1943.

Manual

Although the work with yellow fever had demonstrated the value of a written service manual for the orientation of all administrative sections of the Service, the development of routines in the work of the Malaria Service of the Northeast rapidly followed by the disappearance of gambiae account for the fact that the writing of the manual was begun only after it was almost certain that no more gambiae existed in Brazil. This manual was largely written in 1941 and was finally completed in January 1942. The manual, comprising seven sections, gives a detailed description of the organization of the anti-aegypti fight as it was waged at the height of the campaign. The sections contain information and detailed instructions for the various branches of the Yellow Fever Service, as may be seen from the titles: general administration, routine organization of work in urban centers, complementary services, special services, organization of work in the interior, statistics, legal enforcement. It also contains forms used by all branches of the Service.

SPREAD AND RETREAT OF GAMBIAE, 1939 TO 1940

SPREAD FROM BASE LINE OF 1938 SURVEYS

In spite of the control measures introduced by the Malaria Service of the Northeast during 1939, gambiae continued its march up the various branches of the Jaguaribe, Assú, and Apodí rivers and along the coast of Ceará at such a rate that it was feared the infested territory would become too extensive for available funds to cope with the situation even with adequate methods.

The map opposite shows the known distribution of gambiae previous to December 31, 1938, compared with the areas in which gambiae was found during 1939 and 1940.

1939

Along the coast gambiae was found: between the mouth of the Jaguaribe River and Areias near the border of Rio Grande do Norte;[1] between the mouth of the Jaguaribe River and Fortaleza

[1] Negative for gambiae 1938 survey (Shannon and Andrade).

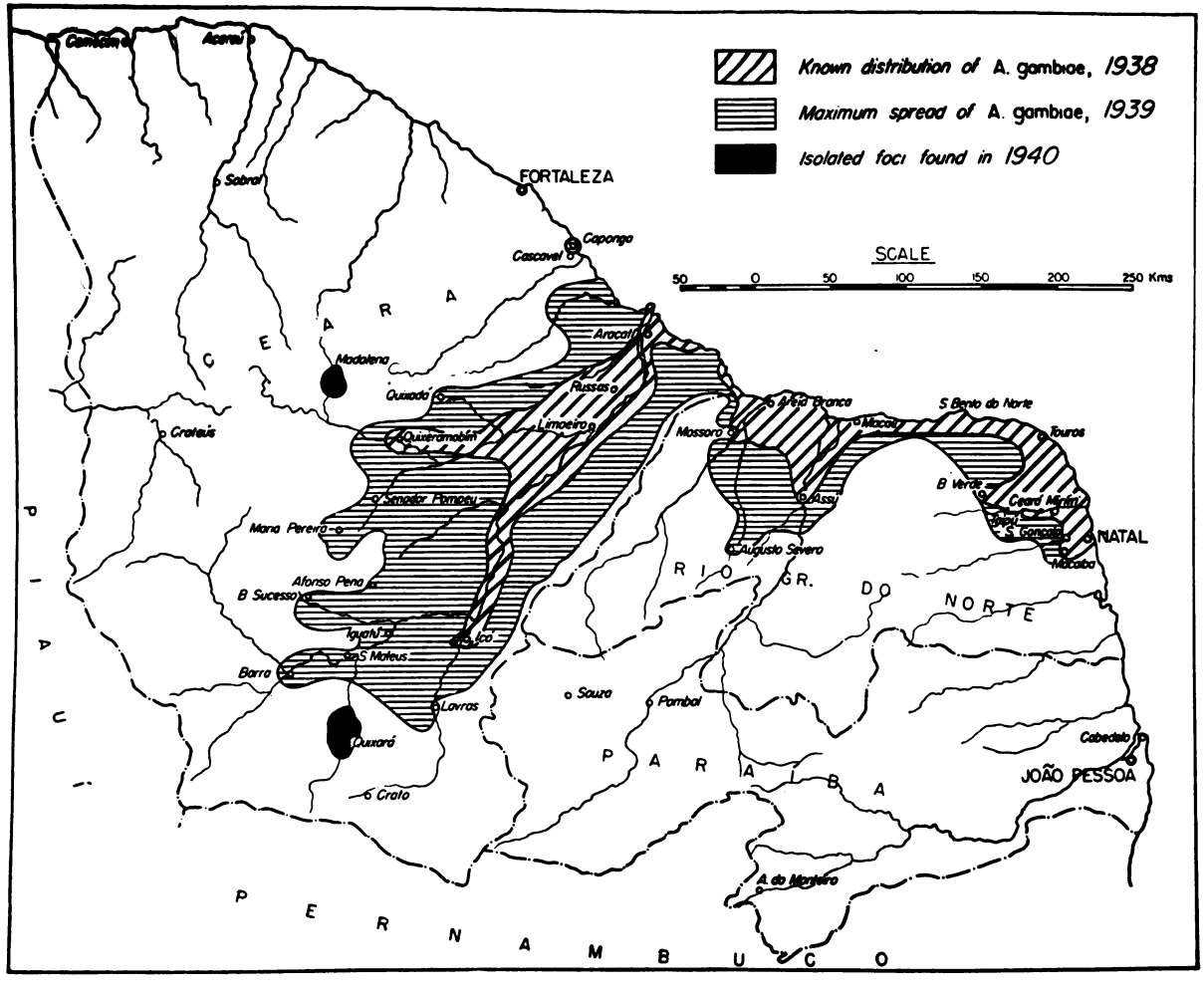

FIG. 68.

as far as Paripueira near the mouth of the Pirangí River and up this river some twenty-five or thirty kilometers to Oiticica;[1] at Caponga, an isolated fishing village only forty-five kilometers from Fortaleza and at about the same distance from the nearest point of infestation in the Pirangí valley.[1] No new infestations were found on the coast after 1939.

In the upper reaches of the Jaguaribe valley gambiae was found: in the Banabuiú valley up to Maria Pereira and Senador Pompeu;[1] on the Jaguaribe River itself to a point a few kilometers above Iguatú;[1] at three isolated foci of infestation: Cariús on the Cariús River, Barra da Conceição on the Jaguaribe River, and Bom Successo, on the Trussú River; in the Salgado River valley at Ouro Branco, and later as far as Lavras.[1]

In Rio Grande do Norte, in 1939, gambiae apparently advanced along the Assú valley to São Rafael, along the Apodí to São Sebastião, and along the Upanema River, a tributary of the Apodí, to Augusto Severo.

Isolated Foci of 1940

Two new widely separated zones of infestation were found in Ceará:

The first in January, three hundred kilometers inland near Quixará on the Cariús River and more than fifty kilometers south of the area at the mouth of this river which had been found infested in 1939.

The second probably represented a long-standing infestation, possibly of a year or longer, in a district not highly favorable to farther spread of the species: an extension of some sixty kilometers west of Quixadá (not to be confused with Quixará), to a small irrigated pocket at Madalena on the Barrigas River, an affluent of the Quixeramobim. This infestation was not discovered until October, some months after the surrounding area, in fact, the entire Division of Quixadá, had been cleaned of gambiae, and some weeks after all known contaminated areas in Brazil were clean.

Unimportant additional extensions were noted early in the year, on the Riacho Bravo, an affluent of the Cariús River, and on

[1] Negative for gambiae 1938 survey (Shannon and Andrade).

the Riacho do Meio, a left bank affluent of the Salgado River, near Icó.

In Rio Grande do Norte no new extensions were registered during 1940.

MECHANISM OF SPREAD

The direction of the prevailing winds may have determined gambiae's initial spread from Natal to the interior of Rio Grande do Norte and may have influenced its failure to go south along the coast from Natal, but there is no evidence that wind direction was an important factor in determining the direction of spread in Ceará, although it may have been at times a factor in accelerating the rate of such spread. The effect of the daily afternoon and evening breeze which blows up the Jaguaribe valley and is known as the "Aracatí," after the place of its apparent origin, is minimized by the fact that this is a dry season wind and is not of importance during the rainy season when dissemination could be most rapid. Field observations indicate that in most cases gambiae spread by infiltration, moving from one breeding place to another.

Several of the extensions found in 1939 and 1940 constituted long jumps from the nearest known foci, which may well have been aided by boat, train, or automobile.

Gambiae probably arrived by boat in the little fishing village of Caponga, fifty kilometers from the nearest known infested area at the mouth of the Pirangí River, whereas, Cariús, Quixadá,[1] and Afonso Pena may have been infested by either train- or automobile-borne mosquitoes. Although some of the infested points lie on rivers of intermittent flow, up which gambiae may have spread by infiltration during the rainy season when breeding pools are plentiful, only to disappear from intermediate points during the dry season, it seems most probable that Ouro Branco, Lavras, Barra da Conceição, Maria Pereira, Quixará, and Madalena were infested by motor transport.

[1] Three gambiae pupae were found in Quixadá in November 1938, but the mosquito was apparently unable to establish itself at the time for no other evidence of local breeding was ever found, although on July 24, 1939, one adult gambiae was captured in a hut sixty meters from the railway station. As repeated searches failed to reveal any other infestation, it is believed that this mosquito must have been carried by train from Senador Pompeu.

RETREAT OF GAMBIAE FROM BASE LINE OF MAXIMUM RANGE

Gambiae's Losses in 1939

It is clear in retrospect, although it was not so apparent at the time, that gambiae had suffered severe losses in territory as a result of the measures taken during the second semester of 1939. Of the three frontier divisions of Ceará, two, Cascavel and Quixadá, had been cleaned, and the third, Icó, had large clean areas although the remaining foci of infestation were widely scattered. Only in the central divisions, Russas and Jaguaribe, was the situation relatively unchanged. Also in Rio Grande do Norte, where the problem was relatively much simpler than in Ceará, the great bulk of the infested area was cleaned before the end of 1939 but small areas of infestation remained along the coast between the Apodí and Assú rivers, in the Ceará Mirím and Maxaranguape valleys, and in the São Gonçalo-Macaíba zone (Fig. 69).

Retreat of 1940

In considering the gambiae situation at the end of 1939, it is necessary to remember that the end of the year corresponds more or less with the end of the dry season, which makes it difficult to discriminate between the results of climatic factors and of control measures. That the retreat of gambiae was due in large part to the attack made by the control service rather than to the effect of the dry season was shown early in 1940 by the rapid pace at which this retreat continued after the rainy season set in, and the failure of gambiae to reappear in many of the cleaned areas which were in contact with still infested zones. During the first half of 1939 the forces lined up against gambiae were almost entirely on the defensive, but by the end of the year they were able to take the initiative, and by using combined antilarval and anti-imaginal measures to force gambiae during 1940 to recede constantly toward the sea.

The maps on page 160 show by months the places in which gambiae was found during 1940 in relation to the known infested area of 1939.

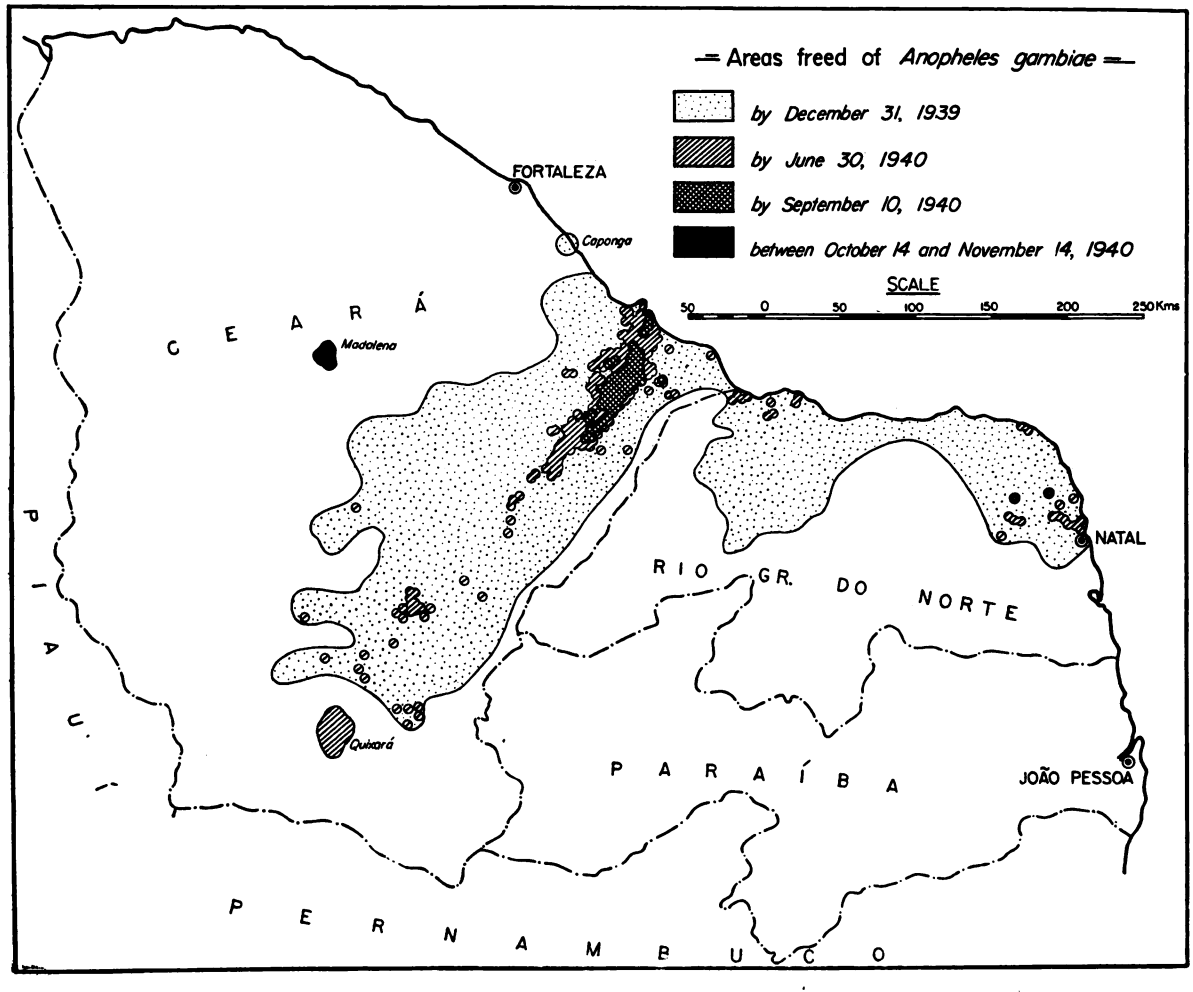

FIG. 69.

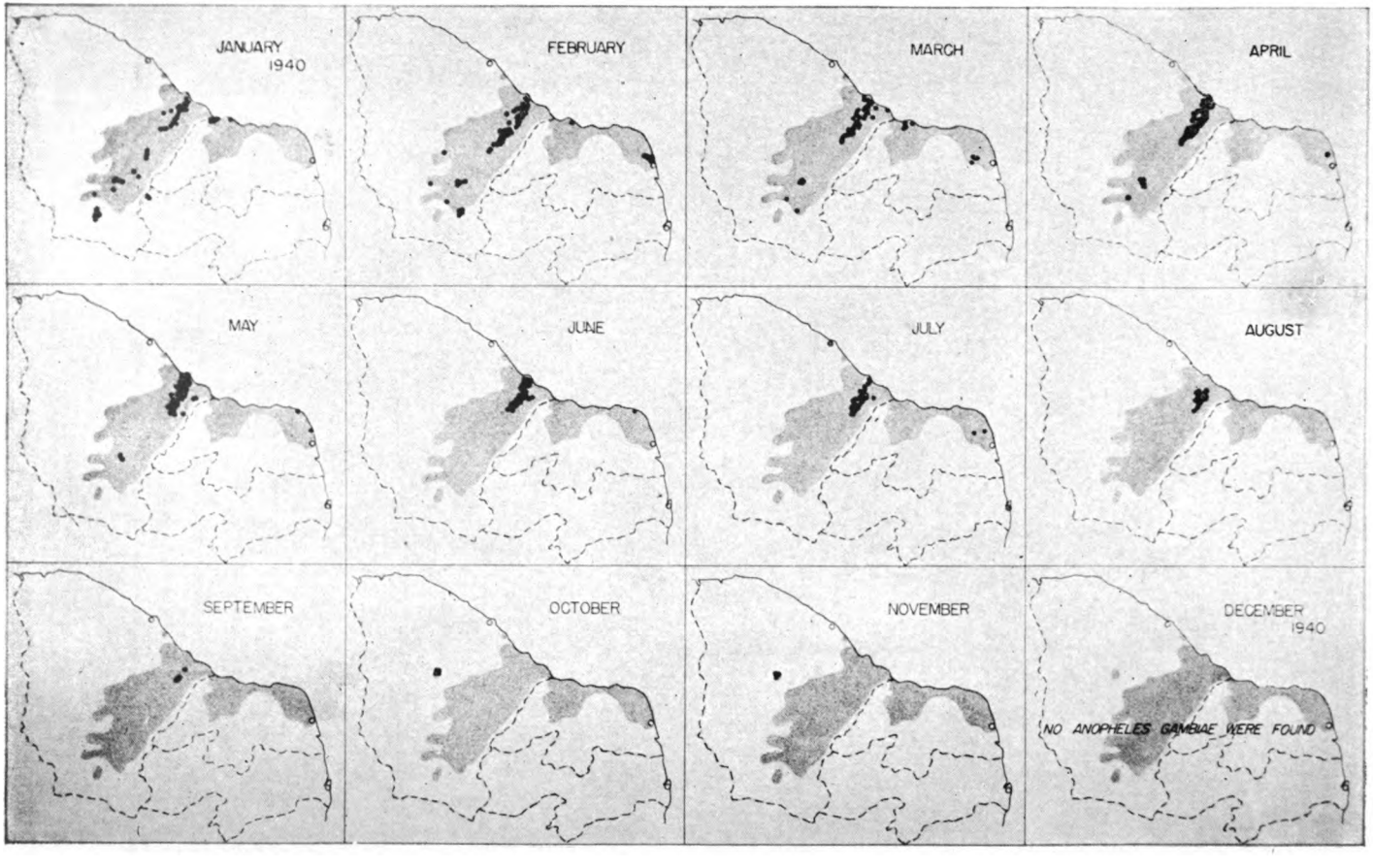

FIG. 70.—Retreat of *Anopheles gambiae*, by months, 1940. Shaded area represents greatest extent of gambiae dissemination; black spots, places where gambiae was found in 1940.

The end of the first semester of 1940 found known gambiae infestation in only two divisions, Russas in Ceará and Ceará Mirím in Rio Grande do Norte. The last gambiae in these divisions were found in July (Ceará Mirím) and September (Russas). The small pocket of previously unknown infestation found in Madalena in October was rapidly cleaned, and the last native-born Brazilian gambiae dates from November 9 and the last larva from November 14, 1940.

TABLE 21

LAST APPEARANCE OF GAMBIAE, BY DIVISIONS

DIVISION	DATE	
	Adult	Larva
Cascavel	December 21, 1939	December 22, 1939
Quixadá	December 14, 1939	November 27, 1939
Madalena* (isolated focus)	November 9, 1940	November 14, 1940
Assú	March 16, 1940	March 11, 1940
Icó	May 3, 1940	May 4, 1940
Jaguaribe	May 27, 1940	May 10, 1940
Ceará Mirím	July 22, 1940	July 16, 1940
Russas	September 9, 1940	September 5, 1940

* Infestation first discovered October 14, 1940.

Mechanism of Offensive

Cumulative Effect of Personnel Released from Cleaned Areas

The discontinuance of control measures in cleaned areas released an ever-increasing number of men for the intensification of work in infested areas. The monthly maps of gambiae distribution during 1940 show clearly the way in which the cleaning of one area was followed rapidly by the cleaning of others as more and more men were concentrated in the infested areas. But this cleaning began at the periphery where farther dissemination was occurring. The lower Jaguaribe valley was the last of the 1939 infested areas to be cleaned, not because it was widely flooded during the rainy season and therefore difficult to work, but rather because the Russas Division, the only division having no frontier with uninfested or unworked territory, was repeatedly drained of per-

sonnel to man the frontier divisions and it was only after other divisions began to be free of gambiae that the Russas Division was given enough men to staff it adequately.

Table 22 shows how additional personnel was poured into the Russas Division in 1940 and how gambiae gave way before it. It also shows that although personnel was reduced in 1941 no reduction was made in the number of houses examined for the presence of gambiae during the first six months of the year.

Paris Green vs. Paris Green and Insecticide

In spite of Barber and Olinger's statement[1] (1931) regarding difficulties of using larvicides against gambiae, most of the credit for the results obtained in 1939 must go to the antilarval work with Paris green, since it was only toward the end of the year that the use of spray insecticide became routine throughout the infested area. The even more rapid results of 1940 may well be due to a number of factors, including improved application of Paris green by a larger number of experienced men. However, a study of the rapidity with which different places were cleaned leaves no room for doubt that house disinsectization with spray insecticide played an important part in hastening the end of gambiae in Brazil.

Insecticide had been used previously for the destruction of mosquitoes infected with yellow fever (Fraga 1930) and malaria (Park Ross 1936; Covell, Mulligan, and Afridi, 1938; Russell and Knipe, 1939), as an approach to disease control; in the antigambiae campaign spray insecticide was used to speed up species eradication and the anti-imaginal service worked side by side with the antilarval service in all infested areas in 1940.

The results obtained by the combined antilarval and anti-imaginal measures were so striking that some workers became overly enthusiastic regarding the latter. As a matter of fact the Malaria Service secured ample proof that antilarval work (Paris green) alone is able to eliminate gambiae, whereas anti-imaginal measures alone were never shown to be effective. However, spray

[1] In regions where *A. gambiae* abound, antilarval measures meet with special difficulties. Larvae are adapted to a great variety of breeding places and their development is rapid, enabling them to take advantage of very temporary collections of water. . . . We doubt if any larvicide campaign (as opposed to drainage and permanent work) can alone cope with conditions found in West Africa.

TABLE 22

VARIATION OF PERSONNEL, SURVEY AND CONTROL MEASURES, AND ANOPHELES GAMBIAE, RUSSAS DIVISION, 1940 AND 1941

1940	PERSONNEL*	PARIS GREEN USED	HOUSES SPRAYED	HOUSE CAPTURES			WATER COLLECTIONS			PLACES WITH GAMBIAE
				Searched	With Gambiae	Percentage	Examined	With Gambiae	Percentage	
January	462	1,503	4,479	1,504	36	2.4	97,430	40	0.041	26
February	672	2,241	12,680	5,404	226	4.2	154,574	122	0.079	62
March	750	3,103	13,788	22,626	1,515	6.7	235,523	105	0.045	103
April	674	2,386	22,639	13,433	1,766	13.1	174,680	706	0.404	176
May	817	2,195	47,555	20,624	2,232	10.8	206,707	1,368	0.661	223
June	986	3,594	56,011	19,888	966	4.9	160,683	553	0.344	126
July	1,075	9,773	74,737	22,968	722	3.1	203,983	469	0.230	103
August	1,150	11,060	61,566	18,722	46	0.2	221,383	113	0.051	30
September	1,059	8,850	61,857	18,506	1	0.0	183,919	7	0.004	5
October	953	8,036	77,713	21,891	0	0	99,155	0	0	0
November	460	3,111	15,207	19,377	0	0	52,276	0	0	0
December	278	376	0	18,552	0	0	22,546	0	0	0
1941										
January	260	0	0	21,476	0	0	22,217	0	0	0
February	256	0	0	19,541	0	0	20,282	0	0	0
March	276	0	0	19,646	0	0	18,621	0	0	0
April	275	0	0	23,716	0	0	25,220	0	0	0
May	313	0	0	21,439	0	0	23,330	0	0	0
June	218	0	0	19,597	0	0	13,765	0	0	0
July	116	0	0	7,322	0	0	5,223	0	0	0
August	123	0	0	8,219	0	0	8,209	0	0	0
September	103	0	0	6,462	0	0	5,307	0	0	0
October	96	0	0	6,370	0	0	6,364	0	0	0
November	90	0	0	6,206	0	0	0	0	0	0
December	91	0	0	5,936	0	0	133	0	0	0

* Drug distributors are not included.

insecticide is of great value in reducing the time needed for cleaning a given area. Table 23 shows the time required to eliminate gambiae from certain representative areas, in some of which antilarval measures alone were employed while both antilarval and anti-imaginal measures were used in others.

In considering the results given in Table 23, it must be remembered that the search for adults by house captures is expensive and that searches for larvae were not part of the responsibility of the antilarval inspectors. It is impossible then to state just when many places became negative but information is available as to the last week in which gambiae were found and when the first negative search was made. It must also be remembered that control meas-

ures were generally continued at least three months after the last finding of gambiae; earlier relaxation of such measures with an opportunity for unrestricted breeding might have shown gambiae to be present in some places after both adult and larva searches were negative.

It will be noted that effective cleaning of different districts was possible at the end of the first semester of 1939 with Paris green alone. Later much more rapid results were obtained by using Paris green and insecticide, both applied by trained personnel.

The comparison of results obtained in the year 1931 with those

TABLE 23

PERIOD BETWEEN BEGINNING OF ANTILARVAL AND ANTI-IMAGINAL MEASURES AND DISAPPEARANCE OF ANOPHELES GAMBIAE

LOCALITY	YEAR	WEEK WORK BEGAN*		LAST WEEK POSITIVE FOR*		FIRST WEEK NEGATIVE FOR*		WEEKS POSITIVE	WEEKS TO NEGATIVE
		Paris Green	Insecticide	Adult	Larva	Adult	Larva		
Caiçara	1939	16th†	19th‡	20th	17th	26th	26th	4	10
Assú	1939	18th	—	30th	34th	31st	35th	16	17
São Gonçalo	1939	21st§	—	40th	41st	41st	42nd	20	21
Lake Piató	1939	24th	—	33rd	33rd	34th	34th	9	10
Senador Pompeu	1939	26th	—	38th	27th	39th	29th	12	13
Barroso	1939	37th	63rd	70th	66th	72nd	67th	33	35
Cariús	1939	37th	42nd	40th	38th	44th	39th	3	7
Caponga	1939	43rd‖	43rd‖	43rd	43rd	44th	44th	0	1
Bom Successo	1939	46th	50th	49th	47th	55th	48th	3	12
Forquilha	1939	47th	47th	47th	47th	48th	48th	0	1
Quixará	1940	53rd	54th	53rd	53rd	64th	55th	1	11
Jurema	1940	61st	67th	89th	86th	93rd	88th	28	32
Cumbe	1940	70th§	70th§	73rd	72nd	74th	73rd	3	4
Cór. Rodrigues	1940	80th¶	80th	81st	82nd	82nd	83rd	2	3
Madalena	1940	96th§	97th	96th	98th	97th	99th	2	3

* Counting from first week of the Malaria Service work.

† Paris green with kerosene and water 16th and 17th weeks, with dry sand beginning 18th week.

‡ Single application.

§ Two applications weekly.

‖ Three applications in 2 weeks.

¶ Six applications in 4 weeks, Paris green in kerosene and water.

of 1939 and 1940 is very striking. In 1931, the Yellow Fever Service succeeded in finding one adult gambiae in each of the last three weeks of a thirty-two week campaign at Natal, in which the attack against gambiae was based on the use of Paris green. In 1939, Senador Pompeu was cleaned in thirteen weeks after an antilarval campaign based solely on Paris green.

The town of Senador Pompeu is on the Banabuiú River far above the highest point at which gambiae was known to be present in 1939. The history of gambiae's invasion of Senador Pompeu and results of this invasion are especially interesting, because the invasion date can be fixed within a few weeks, and the local problem was solved before the introduction of house disinsectization.

Senador Pompeu had been visited in December 1938 and although conditions were ideal for gambiae production, none were found (Shannon and Andrade, 1940). On May 18, 1939, the inspector of the Yellow Fever Service visited every third house in Senador Pompeu searching for *Aedes aegypti* and reported to the Malaria Service that house captures in 355 houses in Senador Pompeu were negative for anopheles. On June 22, in the twenty-fifth week of the year, the Division office in Quixadá was advised that the Yellow Fever Service had revisited Senador Pompeu and found it infested with gambiae. On June 24, antilarval work was begun with the Paris green-dry sand mixture.

That *A. gambiae* in spite of its recent arrival in Senador Pompeu, had become well established is shown by the number of cases of malaria which appeared for treatment during the following weeks. The first three cases of malaria were reported on July 1 and beginning with the twenty-eighth week, new cases of malaria were treated by weeks, as follows: 14, 7, 83, 41, 45, 46, 51, 25, 22, 17, 8, 11. It is impossible now to determine how many of these cases came from the city and how many were from the surrounding area, but it is certain that more than one hundred cases[1] were from within the confines of the city.

After two weeks of the Paris green-dry sand method, gambiae larvae could no longer be found, but adult gambiae were found in

[1] In spite of the numerous cases of malaria registered, there are no reported fatalities from this cause and no increase in the number of burials in Senador Pompeu, the figures for various years being as follows: 1937, 133; 1938, 136; 1939, 134; and 1940, 128.

the houses up to the twelfth week. The rapid drop in the number of gambiae caught in the houses during the early weeks of control measures, suggests that the great mass had disappeared by the end of a six weeks' period after the application of Paris green began.

In comparison with the relatively slow cleaning of Senador Pompeu in 1939, the results of work at Cumbe, a year later, were surprisingly rapid. Cumbe, a small rural district of some sixty houses, close to Aracatí in the lower Jaguaribe valley, was set aside in September 1939 as a laboratory preserve in which no control measures would be applied in order that studies of gambiae under natural conditions could be made. Cumbe was chosen for this purpose because of its natural isolation and its constant supply of water, providing favorable breeding conditions throughout the year. Cumbe is isolated from neighboring districts on three sides by extensive dunes which absorb whatever rainfall there may be and release it slowly as seepage water. At the time control measures were applied in Cumbe, most of the surrounding area was so clean of gambiae that there was little or no danger of reinfestation, and any persistence of gambiae could therefore be attributed to failure of the methods used.

When it became apparent that surrounding areas of the lower Jaguaribe valley would be cleaned of gambiae within a few months, the decision was taken to eliminate gambiae from Cumbe to prevent its becoming a source of reinfestation for clean districts. On April 29, 1940, at the height of the rainy season, twice weekly house disinsectization and application of Paris green were begun (Rainfall: April, 411 mm. or 16.4 in., April 28 to May 25, 225 mm. or 9.0 in.). The area was heavily infested at the time as shown by hand (tube) captures of 800 gambiae by the laboratory personnel during the third week of April and by the capture the following week of over twenty-two hundred gambiae in the houses of Cumbe when the capture squads, working with the umbrella-insecticide technique, made a survey preliminary to the application of control measures.

The disappearance of gambiae was unexpectedly rapid and was carefully checked by both the field and laboratory staff. The last larvae found were discovered seventeen days (May 15) and the last adult twenty-three days (May 21) after control work began. The

first month of work at Cumbe, which covered the eradication of gambiae, cost: labor, $195.30; larvicide, $30.43; insecticide, $24.67; total, $240.40, or $4.17 for each of the sixty houses in this rural district. Whether or not semiweekly work is more economical in the long run than weekly work in cleaning up an area is a question on which experimentation has still to be carried out.

A word should be said in explanation of the apparently high resistance of gambiae in Barroso and Jurema (Table 23). For the Icó Division, Barroso was a central focus which became vitally important only when the peripheral areas of the division were clean. Hence the number of men in that area was small until it became possible to send in enough men to clean it up rapidly. Jurema, a rural district having ninety-six houses, lies in the well-watered, lake-studded area of the lower Jaguaribe River between Russas and União, which was the final central stronghold of gambiae already referred to as having been understaffed until late in the campaign. Antilarval work with Paris green commenced in March after the rainy season began, at a time when transportation was most difficult, much of the region being under water. House disinsectization was begun in April, with the following results:

TABLE 24

HOUSE CAPTURES, JUREMA 1940

MONTH	WEEK	HOUSES	HOUSES WITH GAMBIAE	NUMBER OF GAMBIAE
April	16	96	—	2,310
May	21	96	92	2,913
June	25	96	83	1,186
July	30	96	15	48
August	31	96	5	7
August	34	96	1	2
August	35	96	1	2
September	37	96	1	1*

* The last gambiae found in the entire known-infested region of Brazil which was under control previous to September 1. This specimen was taken from an old spider web and may have been dead before the time of collection.

Jurema and Barroso, therefore, are considered as administrative rather than as technical failures.

SPREAD AND RECESSION OF MALARIA, 1939 TO 1941, IN GAMBIAE-INFESTED REGION

PREGAMBIAE MALARIA

Although malaria has long been a serious problem in many parts of Northeast Brazil,[1] most of the region which came to be infested with gambiae had been previously quite free of the disease, in spite of a heavy seasonal production of certain species of anopheles.[2] The spread and recession of gambiae-transmitted malaria under these conditions was a most interesting biological phenomenon, possibly more interesting even than the spread and retreat of gambiae itself. From the standpoint of the malariologist and of the biologist, it is to be regretted that full advantage was not taken to observe and register in detail the effect of the disturbance of the malaria equilibrium in a nonimmune population with a low parasite rate, in the presence of inefficient native species of anopheles, when a highly efficient vector was introduced; and the rapid return to the initial condition of the then highly infected population after the new vector was removed without, however, altering the incidence of the native anopheles.

FAILURE TO MAKE DETAILED STUDIES

The failure to make more complete and adequate observations on the rise and decline of malaria is part of the price paid for the decision to attempt eradication of gambiae rather than the control of gambiae-transmitted malaria. The study of malaria, which is so essential for the evaluation of the antimalaria campaign has

[1] In Rio Grande do Norte, the coastal plain south of Natal and parts of the Potengí and Ceará Mirím valleys always produce a certain amount of malaria. In Ceará, the well-watered coastal area about Fortaleza, especially east of the city, is mildly malarious, whereas the northwestern part of the state from Sobral to Acaraú, is severely malarious. Barber's survey (1940) included several recognized centers of malaria in these limited malarious zones so that the index given by him for malaria in places never invaded by gambiae fails to represent average conditions throughout the area invaded by gambiae, in which as a rule, malaria was almost nonexistent. This is brought out clearly by the results of the search for lesions of malaria in viscerotomy specimens from the region, Table 10.

[2] Further details will be found in the separate laboratory report (Causey).

little value in a species eradication campaign, since transmission ceases long before the vector species disappears.

The Malaria Service of the Northeast was essentially an anti-gambiae service and as such made no clinical and pathological studies, no studies on the therapeutic value of quinine and atabrin, and no microscopic examination for parasites in the blood of patients either before or after treatment. The only recognition of the existence of malaria in the area was the widespread distribution of antimalaria drugs to all fever cases and the carrying out of an annual survey for ascertaining in a general way the results of the reduction in gambiae density.

ANNUAL HEMOSCOPIC SURVEYS

The eye-witness accounts of the 1938 outbreak quoted in an earlier chapter together with the mortality statistics, need no support from blood and spleen surveys to paint the picture of that year's disaster. The conditions for the year 1939 would have been very similar had it not been for the distribution of drugs, for the number and percentage of infections in many areas were as great as or even greater than that of the previous year. During the early months of 1940 it became apparent that the number of cases was much smaller throughout the entire gambiae-infested area than in the previous year. As gambiae disappeared the reduction in cases was surprisingly rapid and by the time gambiae was out of the picture it was possible to close out the treatment section.

During the years 1939, 1940, and 1941 annual midyear hemoscopic surveys were made by especially trained inspectors who took blood smears from persons throughout the infested area, in accordance with the following instructions:

> equal number of males and females to be examined:
>
> one half of all blood smears to be from persons under fourteen years of age;
>
> four fifths of all smears to be from persons living in rural districts; and
>
> the number of blood smears taken in a given community to be approximately the same in each annual survey.

Surveys had to be made after the wet season but before the dry season was well established and while conditions were highly favorable to transmission.

In 1939 thick smears only were made, but both thick and thin smears were made for each person examined during 1940 and 1941.

The 1939 smears were examined for fifteen minutes before being pronounced negative, but this period was reduced to ten minutes for the following years, since it had been found that only 0.6 per cent of the positive smears of the 1939 survey had been discovered during the last five minutes' examination. This is a justifiable economy, even though the percentage of positives missed in 1940 and 1941 may have been somewhat greater, due to a larger percentage of light infections, once active transmission declined.

Great difficulty was experienced in getting blood smears to the laboratory in suitable condition for examination, due to the dryness of the atmosphere. A special technique which gave excellent results was developed for working with thoroughly desiccated smears (Freitas 1942).

The points chosen for inclusion in the survey are shown on the map opposite and the hemoscopic indices of the annual surveys of 1939, 1940, and 1941, are given by divisions and by type of parasite in Table 25.

It is interesting to note that, although percentages of different species of plasmodium varied somewhat in different divisions and from area to area, the percentage of falciparum infections found was always relatively high. The high fatality of the 1938 outbreak, reported as from 6 to 15 per cent, was attributed by Souza Pinto (Amsterdam 1938) to severe infections of *Plasmodium vivax*, a theory which Schwetz (Amsterdam 1938) questioned, as *P. falciparum* was known to exist in Brazil and was easily transmitted, in other countries at least, by gambiae. As was shown in Table 14, 90 per cent of the 164 infections found at Russas in June 1938 were of *P. falciparum* (E. Chagas, September 1938). The results given in Table 25 also indicate that there was no reason for incriminating vivax as the highly lethal agent in the gambiae-infested area. In 1939 at Gracismões it was found that: "The population of the comparison area was, when our observations started, practically all infected. *Plasmodium vivax* predominated. As soon as the

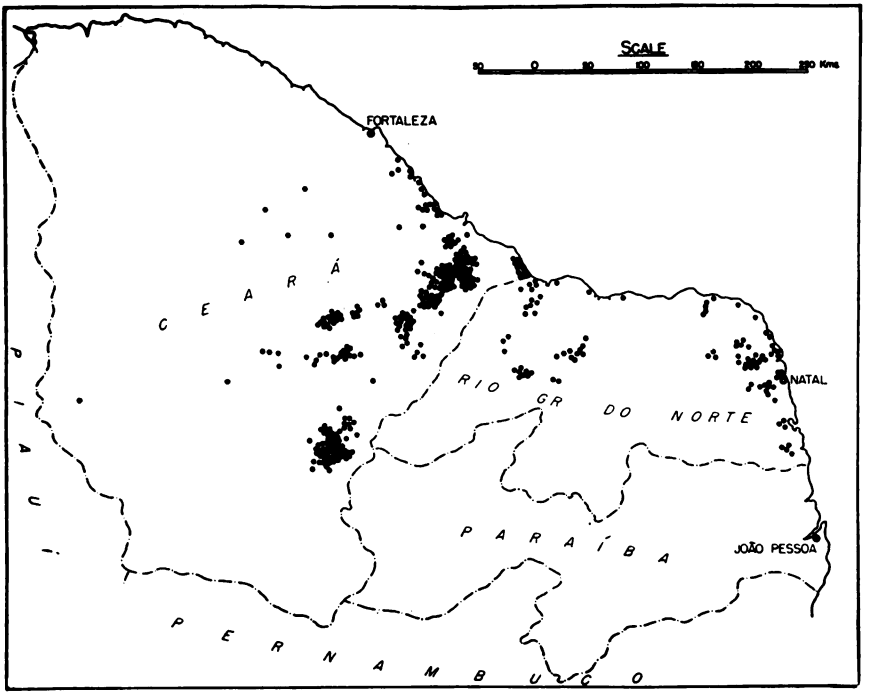

FIG. 71.—Localities included in hemoscopic surveys, 1939, 1940, 1941.

adult density became higher, falciparum infections became prevalent and this continued to be observed until the gambiae density again dropped" (E. Chagas 1940).

This suggests that the erroneous conclusion regarding predominance of vivax was probably based on an inadequate series of examinations at a time when active transmission was greatly reduced.

The high falciparum rate found in Northeast Brazil is in agreement with the observation in India that fulminant epidemic malaria depends on widespread infection with the malignant tertian parasite (Gill).

There is no evidence, then, for the suggestion made that gambiae-transmitted vivax infections are more dangerous than those in which other anopheles have been the vectors.

TABLE 25

HEMOSCOPIC INDICES

(Routine Examinations)

PLASMODIUM SPECIES, BY DIVISIONS

1939, 1940, and 1941

DIVISION	YEAR	DATE OF COLLECTION	BLOOD SMEARS			TYPE OF PARASITE								INFECTIVE CASES WITH GAMETOCYTES	
			EXAMINED	Positive		Plasmodium Vivax		Plasmodium Falciparum		Plasmodium Malariae		Mixed Infections			
				Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Cascavel	1939	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	1940	July and August	783	91	11.6	46	50.5	48	52.4	0	0.0	3	3.3	12	13.2
	1941	July and August	718	6	0.8	3	50.0	3	50.0	0	0.0	0	0.0	2	—
Quixadá	1939	July to November	1,140	497	43.6	349	70.2	231	46.5	0	0.0	83	16.7	271	54.5
	1940	July and August	1,702	94	5.5	40	42.6	54	57.4	0	0.0	0	0.0	26	27.7
	1941	July and August	1,485	1	0.1	0	0.0	1	—	0	0.0	0	0.0	0	—
Russas	1939	June to September	5,108	3,916	76.7	1,303	33.3	3,349	85.5	14	0.4	750	19.1	2,276	58.1
	1940	July to October	5,533	663	12.0	105	15.8	565	85.2	0	0.0	7	1.1	289	43.6
	1941	July and August	5,054	55	1.1	10	18.2	45	81.8	0	0.0	0	0.0	19	34.5
Jaguaribe	1939	May to September	1,073	674	62.8	203	30.1	566	84.0	1	0.1	96	14.2	329	48.8
	1940	July	1,346	215	16.0	101	47.0	120	55.8	1	0.5	7	3.3	48	22.3
	1941	July and August	1,297	4	0.3	0	0.0	4	100.0	0	0.0	0	0.0	0	—
Icó	1939	July to September	1,299	591	45.5	432	73.1	245	41.5	0	0.0	86	14.6	228	38.6
	1940	July	1,300	163	12.5	52	31.9	115	70.6	0	0.0	4	2.4	46	28.2
	1941	July and August	1,184	1	0.1	0	0.0	1	—	0	0.0	0	0.0	1	—
Assú	1939	June to September	1,724	1,200	69.6	936	78.0	550	45.8	0	0.0	286	23.8	522	43.5
	1940	July and August	3,193	169	5.3	68	40.2	101	59.8	0	0.0	0	0.0	22	13.0
	1941	July and August	3,461	7	0.2	1	14.3	6	85.7	0	0.0	0	0.0	2	—
Ceará Mirim	1939	June to September	863	481	55.7	411	85.4	150	31.2	0	0.0	80	16.6	155	32.2
	1940	July and August	3,460	311	9.0	141	45.3	189	60.8	7	2.3	26	8.4	117	37.6
	1941	July and August	3,340	10	0.3	4	40.0	7	70.0	0	0.0	1	10.0	6	60.0
Totals	1939	May to November	11,207	7,359	65.7	3,634	49.4	5,091	69.2	15	0.2	1,381	18.8	3,781	51.4
	1940	July to October	17,317	1,706	9.8	553	32.4	1,192	69.9	8	0.5	47	2.7	560	32.8
	1941	July and August	16,539	84	0.5	18	21.4	67	79.8	0	0.0	1	1.2	30	35.7

The relatively high percentage of gametocyte carriers is in agreement with the fact that the population was in great part free of malaria previous to the advent of gambiae. The lowest percentages of gametocyte carriers were found in Cascavel and Ceará Mirím, the two divisions in which nongambiae-transmitted malaria had been and is somewhat of a problem.

Analysis of the data from the parasite surveys by age groups (Table 26) shows that while there were some variations, in general the distribution of parasites was not greatly influenced by age. Sex was also found to have little influence on the rate of infection found in different groups.

In 1941 the rate of infection for children of less than one year of age, while low, was almost the same as that for other age groups. This suggests, since most of these children were born after gambiae was no longer a factor in the transmission of malaria in the region, that the rates registered for the older age groups were in large part due to current infections through transmission by native anopheles rather than to recurrences of previous infections. On the other hand the rapid decline in parasite rates from 1939 through 1941 indicates that, contrary to all expectations, the local anopheles did not become an important factor in the maintenance of transmission even in those areas where gambiae had built up an infection rate of practically 100 per cent in the local population. This finding came as a definite surprise, since it had been assumed that an increased amount of malaria would occur because of the increased number of carriers remaining after the elimination of gambiae.

The decrease in parasite rates observed after 1940 could not be credited to an important extent to medication for this was suspended in September and most of the fever cases took treatment only long enough to break the immediate symptoms of infection. The rapidity of the decline in parasite rates and the absence of any public outcry when all treatment was suspended suggest strongly that undue importance is often attached to relapses in the explanation of cases of malaria which occur in areas where antimalarial measures are being applied. On the other hand, it may be argued that many more relapses might have occurred had the region from which the principal vector was eliminated been one in which

TABLE 26

HEMOSCOPIC INDICES

(Routine Examinations)

MÁLARIA INCIDENCE, BY AGE GROUPS

1939, 1940, and 1941

DIVISION	YEAR	0–12 MONTHS			1–4 YEARS			5–9 YEARS			10–14 YEARS			15–19 YEARS			20–39 YEARS			40 YEARS AND OVER		
		Examined	Positive		Examined	Positive		Examined	Positive		Examined	Positive		Examined	Positive		Examined	Positive		Examined	Positive	
			Number	Per cent		Number	Per cent		Number	Per cent		Number	Per cent		Number	Per cent		Number	Per cent		Number	Per cent
Cascavel	1939	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	1940	24	4	16.7	55	4	7.3	193	15	7.8	219	31	14.2	81	13	16.0	157	15	9.6	54	9	16.7
	1941	38	1	2.6	58	2	3.4	126	2	1.6	110	1	0.9	96	0	0.0	180	0	0.0	110	0	0.0
Quixadá	1939	15	7	46.7	187	83	44.4	195	91	46.7	210	93	44.3	131	56	42.7	221	84	38.0	181	83	45.9
	1940	48	2	4.2	208	18	8.7	277	19	6.9	364	18	4.9	244	10	4.1	397	21	5.3	164	6	3.7
	1941	60	1	1.7	143	0	0.0	200	0	0.0	258	0	0.0	176	0	0.0	408	0	0.0	245	0	0.0
Russas	1939	25	15	60.0	448	334	74.6	770	581	75.4	952	733	77.0	717	561	78.2	1,363	1,069	78.5	833	623	74.8
	1940	129	15	11.6	740	96	13.0	1,059	127	12.0	1,055	127	12.0	618	77	12.5	1,241	160	12.9	691	61	8.8
	1941	260	1	0.4	522	1	0.2	839	12	1.4	776	9	1.2	612	5	0.8	1,290	15	1.2	755	12	1.6
Jaguaribe	1939	15	13	86.7	78	43	55.1	243	171	70.4	378	247	65.3	232	128	55.2	92	53	57.7	35	19	54.3
	1940	37	6	16.2	144	22	15.3	275	39	14.2	247	39	15.8	165	34	20.6	320	48	15.0	158	27	17.1
	1941	64	1	1.6	134	2	1.5	216	0	0.0	220	0	0.0	156	1	0.6	291	0	0.0	216	0	0.0
Icó	1939	24	13	54.2	172	70	40.7	193	83	43.0	225	99	44.0	212	99	46.7	339	166	49.0	134	61	45.5
	1940	38	5	13.2	116	22	19.0	205	32	15.6	305	38	12.5	187	15	8.0	328	39	11.9	121	12	9.9
	1941	60	0	0	118	1	0.8	178	0	0.0	195	0	0.0	136	0	0.0	316	0	0.0	181	0	0.0
Ceará Mirím	1939	2	1	50.0	63	40	63.5	189	108	57.1	224	115	51.3	128	77	60.2	171	96	56.1	86	44	51.2
	1940	59	3	5.1	244	39	16.0	564	80	14.2	703	69	9.8	460	40	8.7	975	53	5.4	455	27	5.9
	1941	142	0	0.0	297	1	0.3	447	1	0.2	529	3	0.6	403	1	0.2	965	3	0.3	557	1	0.2
Assú	1939	0	0	—	58	39	67.2	259	193	74.5	426	310	72.8	270	175	64.8	457	328	71.8	254	155	61.0
	1940	79	4	5.1	219	15	6.8	471	23	4.9	744	32	4.3	395	31	7.8	847	39	4.6	438	25	5.7
	1941	139	0	0.0	317	0	0.0	497	2	0.4	578	2	0.3	408	0	0.0	1,010	3	0.3	512	0	0.0
Totals	1939	81	49	60.5	1,006	609	60.5	1,849	1,227	66.4	2,415	1,597	66.1	1,690	1,096	64.9	2,643	1,796	68.0	1,523	985	64.7
	1940	414	39	9.4	1,726	216	12.5	3,044	335	11.0	3,637	354	9.7	2,150	220	10.2	4,265	375	8.8	2,081	167	8.0
	1941	763	4	0.5	1,589	7	0.4	2,503	17	0.7	2,661	15	0.6	1,987	7	0.4	4,460	21	0.5	2,576	13	0.5

malaria had long been present, with the development of large numbers of chronic infections.

The 1939 index gives a cross section of malaria incidence at the end of the wet season before antimosquito measures had begun to modify it perceptibly but after a great deal of therapy had been given. As even a small amount of quinine or atabrin causes malaria parasites to disappear from the blood stream, the real index of malaria infection would undoubtedly have been much higher. The 1940 index shows the incidence of malaria during the last months of the gambiae reign while that of 1941 gives the picture a full year after practically all transmission by gambiae had ceased.

The high 1939 gametocyte carrier rate of 33.7 per cent among those examined (Table 25) shows how easy was the transportation of the seeds of infection from one place to another and how inefficient in the sterilization of cases was the routine treatment with quinine and atabrin meted out by the Malaria Service of the Northeast. In 1940 this gametocyte rate had dropped to 3.2 per cent and in 1941 to less than 0.2 per cent.

It is especially difficult to explain the low 1941 indices in the Ceará Mirím Division, where a certain amount of pregambiae malaria existed and where an appreciable number of cases were being reported in August 1940 just previous to the closing of the treatment campaign and shortly before antimosquito measures were discontinued. It hardly seems reasonable to attribute the absence of infections in 1941 either to treatment of cases or to elimination of local mosquitoes by measures intended only for gambiae and discontinued many months previously. The explanation may lie in the fact that in the region as a whole rainfall was somewhat less than in previous years which caused a natural reduction in the amount of anopheles breeding.

PRE- AND POSTGAMBIAE MORTALITY

The figures for total mortality for the six-year period, 1936 to 1941, for ten localities in which gambiae-transmitted malaria became a serious problem are compared in Table 27, with those for the mortality of ten other localities in which gambiae had no apparent influence. The figures presented fail to give the whole pic-

ture since the Yellow Fever Service, after a period of five years in which yellow fever had not been found in Northeast Brazil, discontinued viscerotomy at many places in the gambiae-infested region at the end of the first semester of the year 1938. This interruption of viscerotomy probably affected only slightly the statistics of places where gambiae was not present, but in places where

TABLE 27

TOTAL DEATHS IN TEN CEARÁ LOCALITIES

INVADED BY ANOPHELES GAMBIAE

LOCALITY	DEATHS					
	1936	1937	1938	1939	1940	1941
Aracatí	197	204	321	235	138	161
Jatobá	51	59	95	70	35	48
Limoeiro	141	293	534	336	137	258
Palhano	75	86	113	120	39	74
Quixará	225	306	533	254	136	252
Russas	443	508	1,451	334	262	407
Santo Antonio	18	35	77	63	25	34
União	261	386	372	196	131	133
Barra do Sitiá	47	42	50	109	23	55
Jaguaribe	82	95	84	166	66	91
Total	1,540	2,014	3,630	1,883	992	1,513

NOT INVADED BY ANOPHELES GAMBIAE

LOCALITY	DEATHS					
	1936	1937	1938	1939	1940	1941
Mecejana	230	321	199	240	276	261
Quixará*	118	128	104	135	125	197
Bananeiras	127	116	98	108	116	146
Alagoinha	169	176	128	123	112	104
Nova Floresta	30	45	23	25	33	33
Tapuiará	24	34	30	33	26	40
Pereiro	67	34	14	61	52	71
Lavras*	318	333	326	328	171	224
Olho d'Agua	53	47	38	20	31	67
Saboeiro	39	66	56	51	57	59
Total	1,175	1,300	1,016	1,124	999	1,202

* Invaded but cleared of gambiae before malaria transmission took place.

gambiae became very active there were often not enough well persons left in a community to take the bodies of those who died to the reduced number of cemeteries within a given radius authorized by the Yellow Fever Service. The result was that clandestine burials were common and eventually the local authorities permitted the reopening of cemeteries which had previously been condemned and closed because of their distance from the nearest registry office. The relative increase in mortality for places infested with gambiae is therefore undoubtedly much greater than indicated by available data.

The 1939 reduction in mortality to below that of 1938 is attributed to the distribution of drugs to fever cases in that year. This is especially striking in the statistics for the county seat of Russas (Table 28) where antimosquito measures were not efficiently organized until 1940.

The 1940 and 1941 reduction to below that of previous years is largely due to the absence of gambiae. It is, of course, impossible to determine to what extent the reduction in mortality in the gambiae area in 1939 and 1940 was due to the absence of candidates for death who had fled from the gambiae-infested areas. The 1941 increase over 1940 brings the total back to the 1936 level.

TABLE 28

MORTALITY STATISTICS OF THE COUNTY SEAT OF RUSSAS

MONTH	1936	1937	1938	1939
January	35	64	50	17
February	37	31	65	14
March	78	107	46	20
April	60	82	179	50
May	29	55	327	41
June	33	23	300	38
July	34	19	185	28
August	26	15	161	36
September	17	21	64	29
October	31	18	30	24
November	32	31	23	20
December	31	42	29	17
Total	443	508	1,459	334

LOCAL EFFECT OF A. GAMBIAE

Attention has already been called to the serious outbreak of malaria which occurred in Natal in 1930 and which had begun before the presence of the species was discovered, although the area in which the mosquito was breeding was still very limited. The rapidity with which malaria outbreaks can occur following the introduction of gambiae in a nonmalarious district is indeed surprising; on the other hand, the possibility that the arrival of gambiae in a community may not cause any local reaction in the absence of gametocyte carriers should not be overlooked.

Gambiae without Gametocyte Carriers

Gambiae was observed in a number of places where its arrival had been so recent that it had not yet caused an outbreak of malaria, in many cases apparently because of a lack of gametocyte carriers. No malaria was ever observed as a result of gambiae's penetration above Iguatú, on the Jaguaribe River, nor above Ouro Branco, on the Salgado River. However, the most striking instance of gambiae's invading a community without causing malaria was at Madalena where there is every reason to believe that gambiae was present for at least a year and maybe longer, without the occurrence of a recognized outbreak.

Gambiae with Gametocyte Carriers

Caiçara, a village of some six hundred inhabitants, on the coast east of the mouth of the Jaguaribe, was free of gambiae on November 9, 1938 (Shannon and Andrade), but was found heavily infested four months later (second week in March 1939) during the investigation of an outbreak of malaria which had begun in January. It was impossible to organize efficient control measures or even an adequate treatment campaign at the time, and by early May the authorities reported that only three persons in the village (0.5 per cent of the population) had escaped an attack of the disease. At that time adult gambiae were found in all of 104 houses searched. It is impossible to say how many of the bodies buried at Caiçara were those of people who lived in the village and how many came from the surrounding districts, but it is nevertheless interesting to see how gambiae affected the number of burials in

the village. No data are available for 1937, but during the years 1936 and 1938, a total of forty-five and sixty burials respectively took place, the maximum in any one month for each year being fourteen burials. Previous to January 1939 there was no attempt to register the cause of death, but the local authorities insist that malaria had never been present in the village. The statistics of the years 1939, 1940, and 1941 are given in Table 29. The figures speak for themselves if one knows that the efficient application of Paris green at Caiçara began about the second week in May 1939 and was extended as fast as possible to the surrounding districts.

Malaria is not known to have occurred as a result of the infestation of Cariús, Barra, Quixará, Lavras, and Caponga, but it is difficult to say whether this absence of malaria was due to absence of gametocyte carriers, to a limited period of infestation before discovery, or to the fact that the adult mosquito was immediately attacked in all new foci found after the middle of the year 1939. Probably very few places remained free of gametocyte carriers due to the wholesale exodus of those who were able to flee from the epidemic areas, the sick and convalescent among the refugees carrying the parasites with them to clean areas.

TABLE 29

CAIÇARA MORTALITY STATISTICS

1939 to 1941

MONTH	1939		1940		1941	
	Total	Malaria	Total	Malaria	Total	Malaria
January	12	4	4	1	3	0
February	19	8	3	1	0	0
March	23	23	3	0	6	0
April	37	36	6	1	10	0
May	64	59	7	0	2	0
June	24	24	8	1	4	0
July	19	19	3	0	5	0
August	9	7	5	2	7	0
September	10	9	4	0	3	0
October	12	12	3	0	1	0
November	7	6	0	0	6	0
December	6	5	5	0	5	0
Total	242	212	51	6	52	0

STATISTICAL SUMMARY OF THE MALARIA SERVICE OF THE NORTHEAST

In considering the statistical tables and maps showing the growth and termination of the Malaria Service of the Northeast, it must be remembered that the development of the Service took place in the face of rapid expansion of the infested area and that the post-gambiae reduction in these activities was cautiously based on extremely conservative interpretations of negative findings. Had the problem been the eradication of gambiae from a definitely circumscribed area, such as an island or an isolated region in which the species had reached equilibrium, a much more gradual development could have been undertaken and both active control measures and posteradication observation could have been limited to shorter periods than were adopted in Brazil.

No one could foresee the rapidity of gambiae's retreat in 1940, the fantastic reduction in the number of cases of malaria to be treated, or the possibility of early discontinuation of antilarval measures. As a result the Malaria Service found itself with large and valuable stocks of quinine, atabrin, Paris green, and kerosene on hand at the end of the campaign, in addition to large amounts of office and disinsectization equipment, cars, trucks, and other materials. These supplies, valued at 3,500 contos ($175,000 U.S.), without making any allowance for increased war prices, were turned over to the Ministry of Health by action of the Board of Scientific Directors of the International Health Division of The Rockefeller Foundation at the end of June 1942, when the Malaria Service of the Northeast was disbanded. Fortunately an important malaria service in the Amazon which needed and was able to use almost all of these materials was being organized just at the time they became available.

The tables in this section are grouped for ease of reference by expenditures, personnel, treatment, surveys of distribution of *A. gambiae,* and antilarval and anti-imaginal measures.

TABLE 30

TOTAL EXPENDITURES, BY QUARTERS

1939 Through First Semester 1942
(in United States Dollars)

QUARTER	1939	1940	1941	1942
First	$ 45,445.38	$310,250.60	$125,000.00	$ 68,614.93
Second	148,138.50	287,152.29	124,906.55	47,233.58
Third	134,328.39	227,558.49	103,304.84	—
Fourth	278,497.63	166,112.41	73,026.68	—
Total	$606,409.90	$991,073.79	$426,238.07	$115,848.51

TABLE 31

DISTRIBUTION OF EXPENDITURES, BY ITEMS*

1939 Through First Half 1942
(in United States Dollars)

ITEM	EXPENDITURES				TOTAL
	1939	1940	1941	First Half 1942	
Doctors	$39,588.93	$60,224.54	$40,992.76	$14,885.36	$155,691.59
Office Personnel	13,998.92	27,842.36	29,563.57	10,096.30	81,501.14
Field Personnel	206,218.47	532,687.56	223,646.39	44,129.68	1,006,682.10
Travel	32,766.51	68,411.67	52,786.96	12,576.81	166,541.95
Rent, Light, and Telephone	2,715.82	4,327.99	3,769.95	1,473.27	12,287.04
Supplies and Equipment	67,559.78	61,643.22	11,348.07	3,310.19	143,861.26
Contingent	6,512.33	18,339.38	6,644.90	3,173.97	34,670.57
Freight and Cartage	18,321.92	24,429.26	5,977.05	3,754.04	52,482.27
Automobiles, Trucks (purchase and repair)	51,248.39	47,577.01	27,020.45	21,800.14	147,646.00
Revenue Stamps	91.24	218.38	148.59	42.77	500.98
Telegrams and Postage	751.61	661.93	413.01	289.48	2,116.03
Insecticide	14,956.01	77,337.76	23,080.83	—	115,374.60
Experimental Animals	33.95	58.58	95.54	3.16	191.24
Larvicide	53,061.66	60,920.46	22.42	—	114,004.53
Mapping Supplies	7,827.56	2,408.14	726.48	313.34	11,275.52
Drugs	90,756.80	3,985.55	1.10	—	94,743.45
Total	$606,409.90	$991,073.79	$426,238.07	$115,848.51	$2,139,570.27

* Each year's budget was available for expenditure without restriction, thus facilitating alteration of program to meet actual situations. Separate financial reports to the Brazilian Government and The Rockefeller Foundation were prepared each month, books being audited yearly by a well-known firm of international chartered accountants.

TABLE 32

TOTAL EXPENDITURES, BY YEARS AND BY UNIT MAKING DISBURSEMENT

1939 Through First Quarter 1942
(in United States Dollars)

UNIT	EXPENDITURES				TOTAL
	1939	1940	1941	First Quarter 1942	
Rio and New York Offices, The Rockefeller Foundation	$249,230.08	$225,863.22	$48,702.86	$10,342.50	$534,138.66
Purchases of Antimalaria Service	14,041.49	—	—	—	14,041.49
Central Office, Fortaleza	63,763.54	42,181.69	30,953.13	8,603.04	145,501.40
Central Office. Survey squads	—	2,640.17	26,136.03	2,844.33	41,620.53
Cartographic Section	6,533.75	12,523.44	10,552.49	3,256.76	32,866.44
Epidemiological Section	—	4,391.30	4,360.96	—	8,752.26
Cooperative Study of Control Methods*	—	2,748.94	—	—	2,748.94
Maritime Division	2,167.32	14,848.14	—	—	17,015.46
Central Laboratory	10,205.88	14,047.21	16,940.52	3,870.65	45,064.26
Assú Division	32,672.26	67,755.17	46,348.04	7,920.57	154,696.04
Cascavel Division	12,133.53	55,369.01	21,856.38	2,598.11	91,957.03
Ceará Mirím Division	37,464.86	100,291.89	43,722.23	7,664.37	189,143.35
Icó Division	65,370.19	131,267.40	59,766.39	9,141.51	265,545.49
Jaguaribe Division	10,700.55	78,165.76	20,198.19	2,177.14	111,241.64
Quixadá Division	40,176.80	71,905.83	52,532.14	6,082.81	170,697.58
Russas Division	61,949.65	167,074.62	44,168.71	4,113.14	277,306.12
Total	$606,409.90	$991,073.79	$426,238.07	$68,614.93	$2,092,336.69

* Studies of the Division for Studies on Endemic Diseases, of the Oswaldo Cruz Institute, under direction of E. Chagas.

TABLE 33

CATEGORIES OF PERSONNEL, BY QUARTERS

1939 Through First Half 1942

CATEGORIES	1939				1940				1941				1942	
	FIRST	SECOND	THIRD	FOURTH	FIRST	SECOND	THIRD	FOURTH	FIRST	SECOND	THIRD	FOURTH	FIRST	SECOND
Doctors	19	34	33	49	49	48	39	34	31	31	24	22	21	7
Secretaries	7	10	10	12	11	10	12	12	8	8	6	6	6	2
Cashiers	1	4	3	3	3	3	3	3	5	5	6	5	5	2
Statistical Clerks	—	—	—	2	14	21	22	21	22	24	20	12	11	6
Office Clerks	4	6	4	7	10	19	22	15	18	19	11	7	6	9
Storekeepers and Assistants	5	6	5	13	16	18	17	15	15	13	12	10	10	7
Typists	6	14	20	24	25	24	26	30	32	29	25	22	20	9
Janitors and Servants	9	19	17	20	17	25	24	23	28	31	22	15	14	5
Cartographers and Assistants	2	6	8	13	5	7	5	5	5	5	5	5	4	11
Technical Assistants	6	8	15	15	6	6	7	7	5	7	3	3	3	3
Microscopists and Assistants	3	4	5	5	12	38	43	19	28	23	16	9	9	14
Chief Inspectors: Division	—	1	4	15	22	28	33	27	25	24	14	8	8	1
Antilarval	25	60	90	151	159	148	112	8	0	2	3	2	—	—
Maritime	—	—	—	—	5	4	4	0	0	0	0	0	—	—
Drug	—	—	—	—	10	3	0	0	0	0	0	0	—	—
Capture	—	—	—	—	18	43	58	102	106	90	56	51	55	8
Survey	1	1	—	—	0	36	64	15	10	11	14	8	5	1
Disinsectization	—	—	—	—	0	1	10	0	0	0	0	0	—	—
Inspectors, Antilarval	240	356	462	833	1,075	942	570	60	29	18	11	11	—	—
Maritime	—	—	—	—	38	43	40	0	0	0	0	0	—	—
Drug	8	176	180	187	129	51	4	0	0	0	0	0	—	—
Capture	—	—	—	—	207	272	366	527	616	533	233	215	220	20
Survey	—	51	57	162	100	301	399	81	50	24	25	20	20	—
Disinsectization	—	—	—	—	102	127	102	9	3	0	0	0	—	—
Apprentices	90	150	178	296	339	251	286	4	53	20	1	0	2	—
Laborers	608	838	377	595	1,169	1,134	697	554	736	548	251	235	220	6
Chauffeurs	10	19	28	45	51	50	54	47	41	36	32	26	26	8
Others	1	6	6	58	54	41	85	69	33	26	31	27	37	13
Total, End of Quarter	1,045	1,769	1,502	2,505	3,646	3,694	3,104	1,687	1,897	1,527	821	719	702	132
Dismissed During Quarter	—	—	687	486	504	808	917	1,584	310	411	700	192	98	582
Grand Total Employed	1,045	1,769	2,189	2,991	4,150	4,502	4,021	3,271	2,207	1,938	1,521	911	800	714

TABLE 34

PERSONNEL DISTRIBUTION, BY QUARTERS

1939 Through First Half 1942

UNIT	1939				1940				1941				1942	
	FIRST	SECOND	THIRD	FOURTH	FIRST	SECOND	THIRD	FOURTH	FIRST	SECOND	THIRD	FOURTH	FIRST	SECOND
Fortaleza Headquarters	32	42	38	53	44	46	44	46	57	51	52	46	46	58
Cartography	1	5	24	30	31	28	38	38	19	14	28	28	38	11
Special Survey Squads	—	—	—	—	—	—	8	60	102	103	72	35	56	25
Epidemiology	—	—	—	—	10	5	4	5	4	13	2	—	—	—
Maritime Division	—	—	7	43	57	61	58	—	—	—	—	—	—	—
Aracatí (Fortaleza) Laboratory	—	20	25	35	31	41	35	39	44	59	47	35	35	18
Cooperative Study of Control Methods*	—	—	—	—	16	10	10	—	—	—	—	—	—	—
Assú Division	169	292	258	272	305	442	172	186	286	190	105	102	97	—
Cascavel Division	—	—	107	196	256	267	200	118	128	75	39	34	36	—
Ceará Mirím Division	197	225	240	318	478	560	651	259	227	154	91	104	113	20
Icó Division	201	483	342	611	811	569	366	242	143	84	33	31	119	—
Jaguaribe Division	—	—	—	368	472	335	251	127	286	305	142	129	29	—
Quixadá Division	167	221	194	271	356	341	207	289	325	261	107	84	88	—
Russas Division	278	481	267	308	779	989	1,060	278	276	218	103	91	45	—
Total, End of Quarter	1,045	1,769	1,502	2,505	3,646	3,694†	3,104	1,687	1,897	1,527	821	719	702	132

* Personnel assigned to the Division for Studies on Endemic Diseases, Oswaldo Cruz Institute.

† The peak payroll, April 1940, carried 4,040 names.

MALARIA SERVICE OF THE NORTHEAST

PERSONNEL EMPLOYED 1939 – 1942

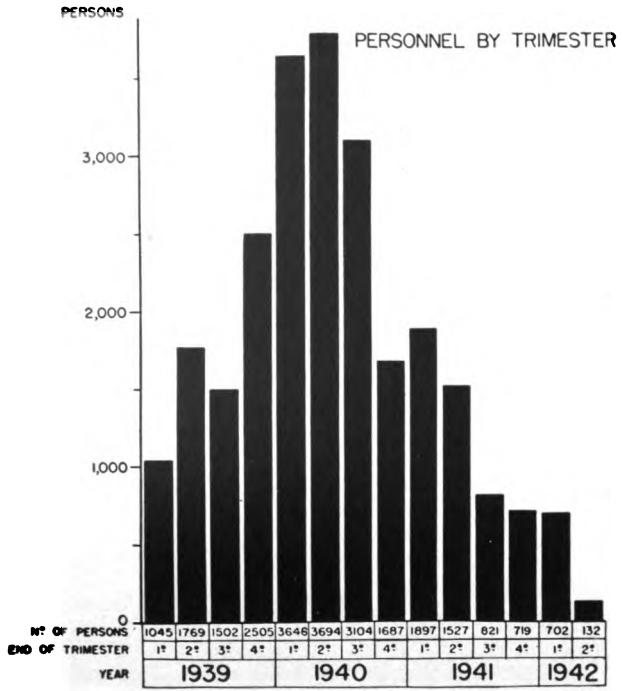

FIG. 72.

MALARIA SERVICE OF THE NORTHEAST

NUMBER OF PATIENTS UNDER TREATMENT BY MONTHS
1939 – 1940

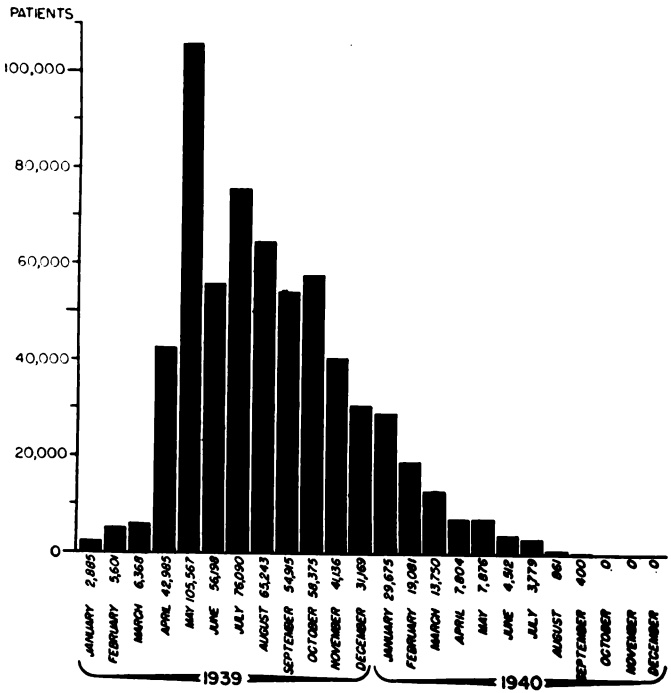

FIG. 73.

TABLE 35

PATIENTS UNDER TREATMENT, BY MONTHS

*1939 and 1940**

MONTH	NUMBER OF PERSONS UNDER TREATMENT															
	Icó		Jaguaribe		Quixadá		Russas		Cascavel		Assú		Ceará Mirím		All Divisions	
	1939	1940	1939	1940	1939	1940	1939	1940	1939	1940	1939	1940	1939	1940	1939	1940
January	—	3,883	360	8,696	—	1,297	1,394	5,716	—	—	747	8,051	384	2,082	2,885	29,675
February	—	1,647	118	8,376	—	831	2,252	6,161	—	—	1,369	1,661	1,862	405	5,601	19,081
March	—	1,130	404	5,795	—	646	2,170	4,849	—	—	1,416	920	2,378	410	6,368	13,750
April	—	1,046	7,577	4,376	5	730	30,510	526	—	71	4,416	640	477	415	42,985	7,804
May	1,563	1,309	12,687	3,720	2,311	732	56,575	811	—	22	17,051	624	15,380	658	105,567	7,876
June	1,582	492	6,759	800	4,121	448	27,157	1,043	686	—	8,829	826	7,064	903	56,198	4,512
July	3,090	149	14,959	—	10,804	377	22,269	1,455	1,630	—	16,146	635	7,192	1,163	76,090	3,779
August	7,447	—	9,880	—	10,783	—	17,675	570	681	—	13,987	111	4,790	180	65,243	861
September	7,846	—	8,542	—	3,621	—	17,614	400	—	—	12,848	—	4,444	—	54,915	400
October	11,075	—	9,336	—	2,612	—	15,035	—	—	—	13,292	—	7,025	—	58,375	—
November	8,006	—	8,491	—	1,905	—	10,133	—	—	—	8,224	—	4,377	—	41,136	—
December	5,271	—	7,680	—	2,854	—	5,457	—	—	—	7,287	—	2,620	—	31,169	—
Total	45,880	9,606	86,793	31,763	39,016	5,061	208,241	21,531	2,997	93	105,612	13,468	57,993	6,216	546,532	87,738

* Number of persons treated during 1939, 185,572; during 1940, 44,179.

TABLE 36

NEW MALARIA PATIENTS REGISTERED DURING 1939 AND 1940

MONTH	ICÓ	JAGUARIBE	QUIXADÁ	RUSSAS	CASCAVEL	ASSÚ	CEARÁ MIRÍM	ALL DIVISIONS
Total, 1939	9,942	26,759	18,576	59,744	—	35,980	34,571	185,572
January	116	573	90	112	—	382	622	1,895
February	49	788	38	138	—	72	77	1,162
March	45	480	47	120	—	22	79	793
April	34	214	45	22	71	13	77	476
May	45	95	34	117	3	10	189	493
June	8	34	18	175	*	17	379	631
July	12	*	9	135	—	7	404	567
August	*	—	*	28	—	6	55	89
September	—	—	—	18	—	*	*	18
Total, 1940	309	2,184	281	865	74	529	1,882	6,124
Grand Total	10,251	28,943	18,857	60,609	74	36,509	36,453	191,696

* Suspended.

TABLE 37

CONSUMPTION OF ATABRIN AND QUININE, 1939 AND 1940

(Atabrin Tablets of 0.10 Grams; Quinine Tablets of 0.25 Grams)

MONTH	ASSÚ		CEARÁ MIRÍM		ICÓ		JAGUARIBE		QUIXADÁ		RUSSAS		CASCAVEL		TOTAL	
	Atab.	Quin.	Atab.	Quin.	Atab.	Quin.	Atab.	Quin.	Atab.	Quin.	Atab.	Quin.	Atab.	Quin.	Atab.	Quin.
Total 1939	511,526	1,322,912	190,141	511,308	11,280	262,517	166,324	262,517	24,488	312,509	1,151,621	1,075,385	—	—	2,055,380	3,747,148
January	53,174	4,576	13,495	875	0	38,004	83,157	0	159	17,680	47,723	0	—	—	197,708	61,135
February	12,652	5,615	6,649	100	0	18,653	74,716	0	101	11,654	56,029	2	—	—	150,147	36,024
March	9,937	5,812	2,559	—	—	13,196	58,407	0	121	8,410	47,715	537	—	—	118,739	27,955
April	—	9,903	3,857	—	0	12,805	50,298	0	2,356	5,911	4,620	515	—	1,077	61,131	30,211
May	—	7,116	4,170	—	0	16,141	48,575	0	4,427	4,253	6,532	463	—	181	63,704	28,154
June	—	9,274	5,618	—	0	8,773	8,633	—	2,289	1,695	70,826	155	—	—	87,366	19,897
July	—	24,045	7,916	—	0	1,805	—	—	2,396	726	18,673	77	—	—	28,985	26,653
August	323	0	1,253	35	—	—	—	—	—	—	5,392	61	—	—	6,968	96
September	—	—	—	—	—	—	—	—	—	—	4,367	48	—	—	4,367	48
Total 1940	76,086	66,341	45,517	1,010	0	109,377	323,786	0	11,849	50,329	261,877	1,858	—	1,258	719,115	230,173
Grand Total	587,612	1,389,253	235,658	512,318	11,280	371,894	490,110	262,517	36,337	362,838	1,413,498	1,077,243	—	1,258	2,774,495	3,977,321

TABLE 38

OBSERVED DISTRIBUTION OF GAMBIAE LARVAE,* BY DIVISIONS

1940 Through First Quarter 1942

DIVISION	1940			1941			FIRST QUARTER 1942		
	Collection of Water Examined	*A. gambiae*	Other Anopheles	Collection of Water Examined	*A. gambiae*	Other Anopheles	Collection of Water Examined	*A. gambiae*	Other Anopheles
Cascavel	807,022	—	185,649	72,875	—	19,045	8,676	—	1,017
Russas	1,812,859	3,483	51,195	105,567	—	9,966	8,305	—	706
Jaguaribe	900,945	40	194,847	195,609	—	20,841	12,871	—	1,299
Icó	2,061,943	45	406,521	55,601	—	9,582	27,681	—	3,067
Quixadá	1,333,008	33	214,678	49,345	—	10,165	5,971	—	413
Assú	742,002	13	21,065	42,980	—	1,248	8,603	—	131
Ceará Mirím	1,554,040	3	20,616	36,006	—	2,924	6,300	—	405
Miritime	298,806	2	13,709	—	—	—	—	—	—
Central Office Squad	8,128	—	1,151	144,477	—	26,427	10,332	—	510
Airport Service	—	—	—	3,010	—	283	2,133	—	614
Total	9,518,753	3,619	1,108,431	705,470	—	100,481	90,872	—	8.162

* 1939: Water collections examined, 897,382; *A. gambiae*, 12,132; other anopheles, 43,114. Available data for 1939 not comparable to those of succeeding years because of changes in division limits during initial organization.

TABLE 39

DISTRIBUTION OF GAMBIAE LARVAE, BY TYPES OF COLLECTIONS OF WATER

1939 Through First Quarter 1942

	WATER COLLECTIONS EXAMINED	TYPES OF COLLECTIONS OF WATER								TOTAL
		Caçimbas in Use	Abandoned Caçimbas	Irrigation Ditches	Drainage Ditches	Springs	Rivers, Pools in River Bed, Lakes and Reservoirs, and Their Margins	Borrow Pits	Other Collections†	
1939*	Total	43,351	29,274	35,426	18,903	4,136	257,443	27,237	481,612	897,382
	Gambiae	113	814	198	190	21	5,370	593	4,833	12,132
	other Anopheles	389	1,725	2,515	1,436	147	20,021	2,033	14,848	43,114
1940	First Quarter	50,574	31,745	52,042	33,307	5,401	307,637	92,100	1,178,371	1,751,177
	Gambiae	15	29	11	0	1	83	80	128	347
	other Anopheles	655	1,159	2,441	2,384	182	15,394	4,008	9,057	35,280
	Second Quarter	41,064	40,525	122,764	76,024	12,517	587,457	227,303	1,790,039	2,897,693
	Gambiae	32	39	8	21	0	128	566	1,855	2,649
	other Anopheles	2,472	6,255	14,890	7,484	557	84,907	31,679	71,180	219,424
	Third Quarter	61,310	103,203	125,184	66,917	15,667	795,239	92,301	2,038,107	3,297,928
	Gambiae	1	35	11	1	0	162	67	313	590
	other Anopheles	3,980	23,744	24,041	10,487	890	254,426	12,874	285,247	615,689
	Fourth Quarter	55,341	104,878	66,558	24,774	5,700	503,863	24,246	786,595	1,571,955
	Gambiae	0	13	0	0	0	18	0	2	33
	other Anopheles	2,093	16,733	12,392	4,095	594	104,314	2,539	95,278	238,038
	Total	208,289	280,351	366,548	201,022	39,285	2,194,196	435,950	5,793,112	9,518,753
	Gambiae	48	116	30	22	1	391	713	2,298	3,619
	other Anopheles	9,200	47,891	53,764	24,450	2,223	459,041	51,100	460,762	1,108,431
1941	Total	52,103	72,728	50,217	12,882	4,774	221,394	21,866	269,506	705,470
	Gambiae	0	0	0	0	0	0	0	0	0
	other Anopheles	1,959	11,289	8,468	2,982	1,051	42,166	3,735	28,831	100,481
1942	First Quarter	8,621	11,396	2,391	1,133	287	19,275	2,899	44,870	90,872
	Gambiae	0	0	0	0	0	0	0	0	0
	other Anopheles	195	1,562	552	286	35	2,416	439	2,677	8,162
1939 to 1942	Grand Total	312,364	393,749	454,582	233,940	48,482	2,692,308	487,952	6,589,100	11,212,477
	Gambiae	161	930	228	212	22	5,761	1,306	7,131	15,751
	other Anopheles	11,743	62,467	65,299	29,154	3,456	523,644	57,307	507,118	1,260,188

* Represents chief inspector's check on antilarval inspectors, findings of special survey squads far beyond frontiers of known infested areas, and investigation of hidden breeding places, instituted after suspension of control measures.

† Other collections include animal wallows, hoofprints, footprints, car and wagon tracks, small depressions.

TABLE 40

HOUSE CAPTURE OF GAMBIAE

1939 Through First Quarter 1942

DIVISION	1939			1940			HOUSES SEARCHED WITH NEGATIVE RESULTS	
	Houses Searched	Houses with Gambiae	Number of Gambiae Found	Houses Searched	Houses with Gambiae	Number of Gambiae Found	1941	First Quarter 1942
Cascavel	15,321	98	1,115	156,791	0	0	133,214	18,911
Russas	20,848	1,467	10,629	203,495	7,510	73,204	165,930	20,906
Quixadá	21,651	623	5,696	160,560	49	479	265,463	23,252
Jaguaribe	5,910	367	1,992	131,944	210	680	114,184	10,530
Icó	52,004	2,291	30,779	304,640	96	306	380,244	52,743
Assú	18,941	141	529	126,771	26	104	213,056	39,632
Ceará Mirím	30,088	1,177	4,396	191,936	23	36	273,937	52,005
Maritime	12,769	3	5	114,975	5	6	—	—
Airport Squads	—	—	—	—	—	—	15,376	1,435
Central Office Squads	—	—	—	3,217	0	0	84,108	11,623
Total	177,532	6,167	55,141	1,394,329	7,919	74,815	1,645,512	231,037

TABLE 41

HOUSE CAPTURE OF GAMBIAE IN RUSSAS DIVISION

1939 Through First Quarter 1942

MONTH	1939				1940				HOUSES SEARCHED WITH NEGATIVE RESULTS	
	Houses Searched	Houses with Gambiae	Percentage of Houses with Gambiae	Number of Gambiae Found	Houses Searched	Houses with Gambiae	Percentage of Houses with Gambiae	Number of Gambiae Found	1941	First Quarter 1942
January	—	—	—	—	1,504	36	2.4	65	21,476	7,546
February	—	—	—	—	5,404	226	4.2	814	19,541	7,652
March	—	—	—	—	22,626	1,515	6.7	20,051	19,646	5,708
April	459	221	48.1	1,092	13,433	1,766	13.1	21,162	23,716	—
May	1,060	277	26.1	5,043	20,624	2,232	10.8	24,268	21,439	—
June	3,652	263	7.2	1,769	19,888	966	4.9	4,007	19,597	—
July	1,974	238	12.1	1,155	22,968	722	3.1	2,770	7,322	—
August	6,324	74	1.2	147	18,722	46	0.2	66	8,219	—
September	2,346	137	5.8	462	18,506	1	0.005	1*	6,462	—
October	2,135	201	9.4	877	21,891	0	0	0	6,370	—
November	1,833	55	3.0	83	19,377	0	0	0	6,206	—
December	1,065†	1	0.1	1	18,552‡	0	0	0	5,936	—
Total	20,848	1,467	7.0	10,629	203,495	7,510	3.7	73,204	165,930	20,906

* The last gambiae in known infested areas was a dried-out specimen found, after disinsectization, in a spider web. Probably dead some days.

† Disinsectization with pyrocide commenced.

‡ Disinsectization with pyrocide suspended.

TABLE 42

LABORATORY EXAMINATION OF MOSQUITO LARVAE AND IMAGOES

1939 Through First Quarter 1942

LABORATORY	1939				1940				EXAMINED WITH NEGATIVE RESULTS			
	LARVAE		IMAGOES		LARVAE		IMAGOES		1941		First Quarter 1942	
	Examined	Gambiae	Examined	Gambiae	Examined	Gambiae	Examined	Gambiae	Larvae	Imagoes	Larvae	Imagoes
Central Laboratory Aracatí and Fortaleza	57,368	3,505	49,152	17,570	1,151,912	16,185*	240,333	55,447†	1,122,804	980,756	62,144	192,367
Field Laboratories (established 1940)												
Assú, October	—	—	—	—	148,513‡	0	19,512	0	6,104	62,089	—	—
Cascavel, June	—	—	—	—	467,057‡	0	67,247	0	—	9,890	—	—
Icó, January	—	—	—	—	2,369,318‡	209	301,350	337	33,549	174,830	—	—
Jaguaribe, June	—	—	—	—	1,272,085‡	1	49,946	1	46,320	18,213	—	—
Ceará Mirím, December 1939	—	—	—	—	254,488‡	394	234,612	194	18,532	288,930	—	—
Quixadá, July	—	—	—	—	1,073,358	636	59,248	801	137,859	108,159	—	—
Total	57,368	3,505	49,152	17,570	7,036,731	17,425	972,248	56,780	1,365,168	1,642,867	62,144	192,367§

* Cascavel 155; Russas 15,837; Jaguaribe 64; Icó 48; Quixadá 56· Assú 25: total 16,185.

† Cascavel 1: Russas 54,380: Jaguaribe 901: Icó 154; Quixadá 6; Ceará Mirím 3; National Yellow Fever Service 2; total 55,447.

‡ The field laboratories were really installed after gambiae was practically extinct, for the purpose of identifying the massive quantities of mosquito larvae and imagoes collected, especially after control measures were suspended. All suspect larvae and imagoes were sent to the Central Laboratory for confirmation.

§ 2 were *Anopheles gambiae* found on planes from Africa.

TABLE 43

SOURCE OF MOSQUITO IMAGOES EXAMINED

1939 to 1942

SOURCE	Year	MOSQUITOES EXAMINED				
		Gambiae	Nyssorhynchus	Stegomyia	Others	Total
Special Squads	1939	—	—	—	—	—
	1940	0	1	608	19	628
	1941	0	3,924	28,760	54,681	87,365
Casacavel Division	1939	1,226	890	126	6,129	8,371
	1940	1	15,089	3,264	60,946	79,300
	1941	0	8,791	656	68,707	78,154
Russas Division	1939*	3,648	2,084	287	8,210	14,229
	1940	54,380	8,002	795	64,220	127,397
	1941	0	7,799	8	28,077	35,884
Jaguaribe Division	1939	1,578	1	0	617	2,196
	1940	901	245	3,748	4,409	9,303
	1941	0	102	14,183	6,599	20,884
Icó Division	1939	10,314	118	800	4,480	15,712
	1940	154	3	780	1,413	2,350
	1941	0	860	21,177	173,806	195,843
Quixadá Division	1939	753	12	200	4,817	5,782
	1940	6	420	42	1,656	2,124
	1941	0	484	45,358	77,612	123,454
Assú Division	1939	—	—	—	—	—
	1940	0	0	115	19	134
	1941	0	108	61,897	17,392	79,397
Ceará Mirím Division	1939	—	—	—	—	—
	1940	3	2,418	283	2,009	4,713
	1941	0	53,348	53,574	252,853	359,775
Maritime Division	1939	51	620	—	2,191	2,862
	1940	0	10,064	18	4,169	14,251
	1941	—	—	—	—	—
National Yellow Fever Service	1939	—	—	—	—	—
	1940	2	131	0	0	133
	1941	—	—	—	—	—
Total	1939	17,570	3,725	1,413	26,444	49,152
	1940	55,447	36,373	9,653	138,860	240,333
	1941	0	75,416	225,613	679,727	980,756
	1942†	2	6,257	27,308	158,800	192,367

* Includes mosquitoes from Assú and Ceará Mirím divisions.

† First quarter. The two gambiae were captured on planes from Africa.

TABLE 44

COLLECTIONS OF WATER TREATED BY ANTILARVAL MEASURES IN VARIOUS DIVISIONS

QUARTER	DIVISION							TOTAL
	Cascavel	Russas	Quixadá	Jaguaribe	Icó	Assú	Ceará Mirím	
1939								
First	0	97,758	0	0	0	0	2,531	100,289
Second	0	2,870,205	293,496	0	426,284	254,902	276,640	4,121,527
Third	114,171	1,634,271	978,908	32,318	1,157,543	515,897	1,035,813	5,468,921
Fourth	626,203	1,198,160	919,068	454,324	3,333,394	806,750	2,012,181	9,350,080
Total	740,374	5,800,394	2,191,472	486,642	4,917,221	1,577,549	3,327,165	19,040,817
1940								
First	1,550,802	4,555,180	2,160,444	1,115,074	5,823,673	1,612,215	4,465,485	21,282,873
Second	1,065,364	6,466,934	2,647,132	1,440,551	5,261,138	3,597,540	10,074,165	30,552,824
Third	523,412	10,135,047	497,170	690,352	337,624	2,541,136	13,465,739	28,190,480
Fourth	83,996	721,630	101,564	41,492	0	0	4,689,213	5,638,895
Total	3,224,574	21,878,791	5,406,310	3,287,469	11,422,435	7,750,891	32,694,602	85,665,072
1941								
First*	0	0	67,503	0	0	0	0	67,503
Grand Total	3,964,948	27,679,185	7,665,285	3,774,111	16,339,656	9,328,440	36,021,767	104,773,392

* Madalena district on Barrigas River.

TABLE 45

ROUTINE ANTILARVAL WORK, BY TYPES OF WATER COLLECTIONS AND METHOD OF TREATMENT

1939 to 1941

YEAR	METHOD OF TREATMENT	TYPES OF WATER COLLECTIONS								TOTAL
		Caçimbas in Use	Abandoned Caçimbas	Irrigation Ditches	Drainage Ditches	Springs	Rivers, Pools in River Beds, Lakes and Reservoirs, and Their Margins	Borrow Pits	Other Collections	
1939 Incomplete	Paris green	66,717	228,681	375,777	253,396	50,808	2,931,158	230,040	7,270,622	11,407,199
	Fill	65,446	305,454	12,290	10,182	837	435,864	51,592	6,095,089	6,976,754
	Oil	3,054	3,618	7,946	3,471	313	30,440	12,257	47,914	109,013
	Drainage	7,694	1,610	13,454	22,421	803	16,621	4,129	6,287	73,019
	Fish*	214,362	11,063	30,818	30,028	11,267	125,087	11,319	40,888	474,832
	Total	357,273	550,426	440,285	319,498	64,028	3,539,170	309,337	13,460,800	19,040,817
1940	Paris green	79,411	390,700	2,019,861	977,031	229,005	8,315,375	1,712,566	63,070,216	76,794,165
	Fill	33,129	190,784	5,216	12,230	1,072	437,163	141,569	7,465,893	8,287,056
	Oil	46	62	267	31	—	727	345	6,774	8,252
	Drainage	2,235	1,829	47,120	51,458	4,637	35,248	28,719	41,585	212,831
	Fish*	182,153	4,584	20,668	31,427	14,602	71,740	6,170	31,424	362,768
	Total	296,974	587,959	2,093,132	1,072,177	249,316	8,860,253	1,889,369	70,615,892	85,665,072
1941	Paris green	29	640	103	127	34	10,252	406	54,759	66,350
	Fill	29	274	—	—	2	38	29	72	444
	Fish*	709	—	—	—	—	—	—	—	709
	Total	767	914	103	127	36	10,290	435	54,831	67,503
TOTAL	Paris green	146,157	620,021	2,395,741	1,230,554	279,847	11,256,785	1,943,012	70,395,597	88,267,714
	Fill	98,604	496,512	17,506	22,412	1,911	873,065	193,190	13,561,054	15,264,254
	Oil	3,100	3,680	8,213	3,502	313	31,167	12,602	54,688	117,265
	Drainage	9,929	3,439	60,574	73,879	5,440	51,869	32,848	47,872	285,850
	Fish*	397,224	15,647	51,486	61,455	25,869	196,827	17,489	72,312	838,309
	Grand Total	655,014	1,139,299	2,533,520	1,391,802	313,380	12,409,713	2,199,141	84,131,523	104,773,392

* Fish already present; they never were distributed routinely by the Malaria Service of the Northeast.

TABLE 46

DISTRIBUTION OF PARIS GREEN (IN KILOGRAMS), BY DIVISIONS AND QUARTERS

1939 Through First Quarter 1941

QUARTER	DIVISION								TOTAL
	Assú*	Cascavel	Ceará Mirím*	Icó	Jaguaribe	Quixadá	Madalena	Russas	
1939									
First	0	0	0	111	0	0	—	450	561
Second	1,440	0	1,350	1,591	0	900	—	1,800	7,081
Third	2,681	360	2,829	13,042	180	3,780	—	3,780	26,652
Fourth	1,840	2,070	3,840	23,958	6,750	6,840	—	4,320	49,618
Total	5,961	2,430	8,019	38,702	6,930	11,520	—	10,350	83,912
1940									
First	2,725	2,844	321	10,164	5,517	6,275	—	6,847	34,693
Second	7,810	2,578	10,466	10,434	7,167	6,243	—	8,175	52,873
Third	5,937	2,517	23,530	1,346	3,190	1,481	—	29,683	67,864
Fourth	0	494	8,248	—	334	—	936	11,523	21,535
Total	16,472	8,433	42,565	21,944	16,208	13,999	936	56,228	176,785
1941									
First	0	0	0	0	0	0	595	0	595
Grand Total	22,433	10,863	50,584	60,646	23,138	25,519	1,531	66,578	261,292

* Represents shipments received at the post and used before the end of the year.

TABLE 47

HOUSES DISINSECTIZED, BY MONTHS AND BY DIVISIONS

1939 to 1941

YEAR	MONTH	DIVISION							TOTAL
		Cascavel	Russas	Jaguaribe	Icó	Quixadá	Assú	Ceará Mirím	
1939	August	609	—	—	—	—	—	—	609
	September	762	—	—	—	—	—	—	762
	October	1,017	—	—	278	—	—	—	1,295
	November	3,777	—	—	3,461	—	—	—	7,238
	December	2,626	1,065	4,683	3,806	1,036	—	—	13,216
	Total	8,791	1,065	4,683	7,545	1,036	—	—	23,120
1940	January	1,765	4,479	11,001	19,060	3,494	1,077	2,366	43,242
	February	2,168	12,680	5,124	21,292	3,184	1,911	2,536	48,895
	March	3,467	13,788	6,661	25,278	3,762	2,403	3,000	58,359
	April	3,859	22,639	8,058	27,038	3,306	4,433	3,065	72,398
	May	1,001	47,555	3,069	26,026	3,687	2,899	3,884	88,121
	June	—	56,011	2,489	4,475	—	2,788	3,764	69,527
	July	—	74,737	1,764	—	—	1,486	3,046	81,033
	August	—	61,566	1,292	—	—	—	1,381	64,239
	September	—	61,857	—	—	—	—	60	61,917
	October	—	77,713	—	—	—	—	—	77,713
	November	—	15,207	—	—	671*	—	—	15,878
	December	—	—	—	—	672*	—	—	672
	Total	12,260	448,232	39,458	123,169	18,776	16,997	23,102	681,994
1941	January	—	—	—	—	1,120*	—	—	1,120
	February	—	—	—	—	819*	—	—	819
	Total	—	—	—	—	1,939*	—	—	1,939

* Madalena.

TABLE 48

CONSUMPTION OF INSECTICIDE (LITERS), BY DIVISION AND BY TYPE OF SERVICE

1939 Through First Quarter 1942

DIVISION	LITERS OF INSECTICIDE CONSUMED												TOTAL			
	House Captures				House Disinsectization				Vehicle Disinsectization							
	1939	1940	1941	First Quarter 1942	1939	1940	1941	First Quarter 1942	1939*	1940	1941	First Quarter 1942	1939	1940	1941	First Quarter 1942
Assú	0	17,995	26,221	3,056	0	5,216	0	0	—	470	0	0	0	23,681	26,221	3,056
Cascavel	0	21,477	14,930	1,003	3,374	3,528	0	0	—	1,514	722	0	3,374	26,519	15,652	1,003
Icó	0	61,255	40,718	3,925	3,143	45,364	0	0	—	848	0	0	3,143	107,467	40,718	3,725
Jaguaribe	0	26,615	18,876	836	1,377	10,399	0	0	—	468	0	0	1,377	37,482	18,876	826
Ceará Mirím	0	27,711	28,596	3,848	0	6,787	0	0	—	615	0	0	—	35,113	28,596	3,848
Quixadá	0	25,551	26,500	2,575	233	3,999	894	0	—	559	18	0	233	30,109	27,412	2,575
Russas	0	43,156	22,977	1,229	520	180,576	0	0	—	251	0	0	520	223,983	22,977	1,229
Central Office Squads	0	0	7,953	880	0	0	0	0	—	0	0	0	0	0	7,953	880
Maritime	0	19,776	0	0	0	0	0	0	—	649†	0	0	0	20,425	0	0
Airport Sentinel Service‡	0	0	1,435	128	0	0	0	0	—	12§	33§	125§	0	12	1,468	253
Total	0	243,536	188,206	17,470	8,647	255,869	894	0	—	5,386	773	125	8,647	504,791	189,873	17,595

* Records not kept for insecticide used in vehicles in 1939.

† Boats.

‡ Covers work in Recife, Natal, Fortaleza, and Belém.

§ Airplanes.

TABLE 49

CONSUMPTION OF INSECTICIDE (LITERS), BY DIVISIONS AND BY QUARTERS

1939 Through First Quarter 1942

YEAR	QUARTER	DIVISION							BOATS PLANES AND SPECIAL SQUADS*	TOTAL
		Assú	Cascavel	Ceará Mirím	Icó	Jaguaribe	Quixadá	Russas		
1939	First	—	—	—	—	—	—	—	—	—
	Second	—	—	—	—	—	—	—	—	—
	Third	—	740	—	—	—	—	—	—	740
	Fourth	—	2,634	—	3,143	1,377	233	520	—	7,907
	Total	—	3,374	—	3,143	1,377	233	520	—	8,647
1940	First	5,707	6,804	7,069	29,810	9,295	6,673	17,593	7,367	90,318
	Second	6,776	7,790	8,798	33,855	9,063	8,006	55,881	6,327	136,496
	Third	4,765	5,707	6,486	23,457	9,414	9,530	95,657	5,870	160,886
	Fourth	6,433	6,219	12,760	20,345	9,710	5,900	54,852	872	117,091
	Total	23,681	26,520	35,113	107,467	37,482	30,109	223,983	20,436	504,791
1941	First	9,736	7,682	12,042	20,605	13,118	9,237	10,415	1,576	84,411
	Second	9,479	5,643	10,017	11,159	3,302	11,089	9,691	2,856	63,236
	Third	4,000	1,477	3,506	5,319	1,438	4,217	1,899	2,311	24,167
	Fourth	3,006	850	3,031	3,635	1,018	2,869	972	2,678	18,059
	Total	26,221	15,652	28,596	40,718	18,876	27,412	22,977	9,421	189,873
1942	First	3,056	1,003	3,848	3,925	826	2,575	1,229	1,133	17,595
Grand Total		52,958	46,549	67,557	155,253	58,561	60,329	248,709	30,990	720,906

* Records not kept for insecticide used in vehicles in 1939.

SPECIAL SECTIONS

CENTRAL LABORATORY

The functions of the Central Laboratory were training of personnel, routine identification of mosquitoes, and research.

Training Personnel

Even before it was adequately installed the Central Laboratory of the Service began training doctors and subordinate personnel in the rapid and accurate identification of the gambiae larva and adult. Practically no one connected with the Service, not even the laboratory staff, had had any previous experience with gambiae and therefore had to start with the very ABCs of the identification of gambiae and of the most common anopheles of the region. A booklet in Portuguese prepared by Shannon, entitled *Distinctions between Anopheles Gambiae and the Native Brazilian Anopheles of Northeast Brazil,* was of great assistance, as were also the observations made in the laboratory. In 1940, as soon as available in sufficient numbers, trained men were sent to all division headquarters where field laboratories were opened for the training of local personnel and for the classification of all larvae and adults collected in each division.

Routine Laboratory Identification

Field laboratories were opened in the following order: Ceará Mirím (December) 1939; Icó (January), Cascavel and Jaguaribe (June), Quixadá (July), Assú (October), 1940. When one considers that during 1940 over seven million larvae and nearly one million imagoes were examined (Table 42) there is little need to discuss the necessity for relieving the Central Laboratory of some of its routine work. Difficulties in the transportation of material made this an especially welcome step to the doctors in charge of divisions, who thus received reports with much less delay. The huge increase over 1939 in the quantity of material examined was a consequence of the policy instituted in 1940, when control measures were being suspended in the various divisions, of depending on larva searches and adult captures to uncover the presence of any hidden gambiae breeding. At first the larva searcher examined with a 10x lens all

larvae collected, and forwarded to the Central Laboratory for confirmation only those larvae identified as gambiae. When the larva search was used as a check on the absence of gambiae from previously infested areas, the inspector was no longer responsible for identification but only for collecting and forwarding larvae from all anopheline foci to the local laboratory for examination.

Study of Methods and Material

During the early part of the campaign, the laboratory was called upon for solutions to many questions as to methods and materials to be used. One of the first problems undertaken was to find characteristics of gambiae that would enable the field inspectors to distinguish it from the other anopheles of Northeast Brazil, at a glance or, at most, with the use of a hand lens.

After examination in the laboratory of a large amount of material, it was observed that *A. gambiae* can be distinguished in the field from the local species of anopheles in the larval, pupal, and imaginal stages. In the larval stage the most reliable characteristic is the lack of pigmentation of the hairs (G. O. Castro), which causes the antennae and the hairs on the thorax and abdomen of gambiae larvae to be much lighter in color than those of Nyssorhynchus. Against a light background, the hairs of Nyssorhynchus larvae are very conspicuous while those of gambiae are practically invisible. Field inspectors, trained in the examination by diffused light of larvae in clean water in a white enameled receptacle rapidly learned to identify gambiae larvae, distinguishing them even when rare in mixed foci. Even the pupa of gambiae can be readily identified, since it does not have the light-colored longitudinal band formed by the grouping of the dorsal abdominal scales of well-developed albitarsis and argyritarsis imagoes, easily seen by the naked eye through the pupal case.

In the field in differentiating gambiae adults from other anopheles, the characteristics stressed were:

last four tarsal segments of the posterior legs of gambiae are almost black, with very small yellowish rings, while those of Nyssorhynchus are almost all white;

basal black spot on the fifth vein is near the base of the wing in gambiae and near the bifurcation in Nyssorhynchus;

abdominal sternites of *A. gambiae* have large white spots, not found in Nyssorhynchus.

In the first months of the application of Paris green, the laboratory was called upon to determine not only the best type of Paris green for use under the conditions existing in Northeast Brazil, but also the best methods of applying it and the optimum proportions of the different diluents. Similar problems had to be solved in connection with insecticide for spraying: What proportions were best? What diluents could be used? What was the time required for efficient spraying? How diminish the fire hazard? The answers to these and other questions were important in determining the details of the techniques adopted.

Biology of *Anopheles Gambiae*

The establishment of a laboratory colony was imperative for the biological study of *A. gambiae*. To avoid the high mortality of mosquito larvae reared in the laboratory, an effort was made to find a suitable diet and method of feeding. After various experiments, yeast and starch were adopted for routine feeding of the larvae which were grown in basins containing sand and water. With this method, a colony was easily maintained to supply larvae and adults for study and experiments, until it was eliminated at the end of August 1940 to prevent all possibility of reinfestation of areas which had been cleaned of gambiae.

A separate report on the ecology of gambiae has been prepared (Causey, Deane, and Deane, 1943) so that only passing mention will be made here of the subjects studied: light intensity and man as factors in attracting gambiae; host preference; feeding habits; susceptibility to malaria; time spent in houses; wind as a factor in dispersion; experimental infection; influence of shade, vegetation and salinity of breeding places; hours of oviposition; viability of eggs; duration of larval and pupal stages; and longevity of adults.

Besides gambiae studies, the laboratory staff made observations on gambiae and malaria under natural conditions at Cumbe.

Ecology, Classification, and Distribution of Other Anopheles

During the routine searches for gambiae larvae and adults a wealth of material on the Brazilian species of anopheles was sent

to the Aracatí laboratory, not only from the States of Ceará and Rio Grande do Norte, but also from the neighboring States of Paraíba, Pernambuco, Piauí, and Maranhão where special investigations of malaria outbreaks were carried out. As a result, it was possible to complete certain studies on the ecology, taxonomy, and distribution of several species of the Nyssorhynchus subgenus.

Malaria at Cumbe

In January 1940 special studies were begun on the incidence of malaria at Cumbe, an isolated well-watered rural district of some sixty families which was reserved untouched by control measures from September 1939 to the end of April 1940 for the study of gambiae under natural conditions. The control service then moved in and eradicated gambiae in May 1940 and, contrary to practice in other areas, continued antilarval work during 1941 testing the possibility of species eradication for Nyssorhynchus. Hence the report on these studies (Causey, Penido, and Deane, 1943) covers malaria with free transmission by gambiae and Nyssorhynchus during several months and the recession of malaria following antigambiae measures and, later, during attack on all anopheles.

EPIDEMIOLOGICAL SECTION

Although a study of the incidence of malaria in the gambiae-infested area was not one of the main objectives of the Service, an Epidemiological Section was organized to take charge of any work done in this connection. During the year 1939, 1940, and 1941 annual hemoscopic surveys were made in the months of July and August, at the beginning of the dry season when conditions were highly favorable to transmission (see pp. 169-175).

COOPERATIVE STUDY OF CONTROL METHODS

When the Malaria Service of the Northeast took charge of the antigambiae campaign, E. Chagas suggested keeping a study area near the county seat of Russas, including the two villages of Gracismões and Timbaúbas, in which his organization could test the effect of insecticide spraying of houses on the reduction of mos-

quitoes and of malaria. Gracismões was left as a control area, while anti-imaginal measures were instituted in Timbaúbas. Later two other small villages were incorporated in the study area: Macambira, where only antilarval work was carried out and Araújos where both antilarval and anti-imaginal measures were applied. These studies could not be brought to a definite conclusion because of the danger of reinfestation of the surrounding territory which by April 1940 was rapidly being cleaned of gambiae.

CARTOGRAPHIC SECTION

The principal function of this section was a compilation from existing data of maps of all the areas (Fig. 74) where anti-gambiae measures were being applied so that suitable limits to the administrative sectors could be ascertained and each zone inspector might know definitely the extent of the area under his immediate control. When first put into use in the field these maps showed many discrepancies which were then communicated to the section for correction on the original drawings. As a result usable field maps showing towns, villages, rivers, and means of communication, covering an area of 116,923 square kilometers in the State of Ceará and 53,003 square kilometers in the State of Rio Grande do Norte, are available for any future work in that region.

The Cartographic Section included a photographic section for the rapid development and printing of air photographs. Its air-mapping activities began after the arrival in December 1939 of an army plane, pilot, and photographer loaned by the Military Geographic Service. This work was interrupted before the end of the year and was only recommenced in July 1940 with the arrival of another army plane and the necessary personnel.

Planimetric maps were compiled from aerial photographs of 10,500 square kilometers of the State of Ceará, covering the lower Jaguaribe basin as far as São José de Jaguaribe and extending along the coast from Caponga to the state boundary at Tibáu. These maps were drawn to a scale of 1:20,000 and 4,632 air photographs were taken over this area.

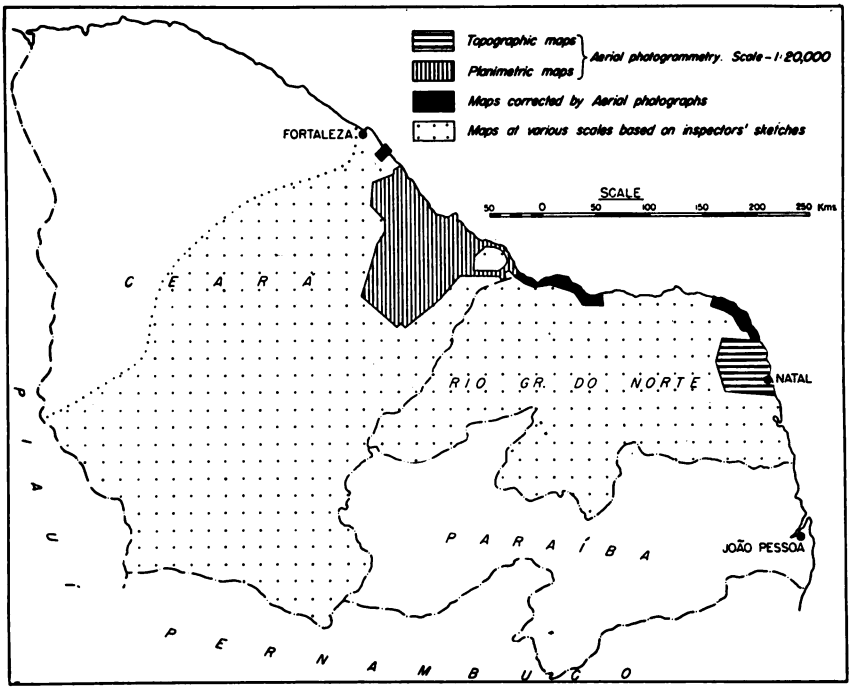

FIG. 74.—Areas mapped by the Malaria Service of the Northeast.

Maps drawn to a scale of 1:20,000, were compiled from air photographs covering an area of 2,200 square kilometers extending from the Maxaranguape basin to a little south of the Parnamirím airport at Natal. Photographs were also taken along the coast from Tibáu to Areia Branca and from Touros to Maxaranguape, making a total of 714 photographs in the State of Rio Grande do Norte.

All field work for controlling aerial photogrammetric mapping has been carefully indexed and filed so that it may be used for future reference by federal and state geographical authorities.

The Cartographic Section also carried out special large-scale mapping of study regions for the laboratory and was in charge of the construction of both portable and fixed fumigation stations.

DISCUSSION

REALITY OF THREAT TO THE OTHER AMERICAS

When the story of the 1938 gambiae-produced epidemic of malaria in Northeast Brazil became known in other countries of the Americas, many health officers grew alarmed over the future safety of their own provinces, whereas others adopted the philosophy of "it can't happen here." Some of the first group, representing several different countries, gathered at the Tenth Pan American Sanitary Conference at Bogotá in September 1938, went so far as to discuss unofficially the need for a common international war chest to finance the attempt to rid Brazil of gambiae. Others believed from the first that gambiae could not be eradicated and that it made little difference to their countries whether it were or not.

In the light of a careful analysis of gambiae's behavior in Africa and in Brazil, it is no exaggeration to say that vital interests of every country in the Americas, except Canada, were probably involved in the struggle with gambiae in Northeast Brazil. The gambiae threat was not limited to an increase in the malaria of regions already malarious, but included the introduction of the disease to many nonmalarious regions and the widespread dissemination of filariasis, of which gambiae is a vector. Probably 90 per cent of the gambiae-transmitted malaria in Brazil in 1938-39-40 occurred among populations entirely unfamiliar with the disease.

Much of *A. gambiae's* success derives from the fact that it is most highly adapted to a simple, almost universal type of breeding place, namely, shallow sunlit pools without vegetation. Gambiae's eventual distribution, then, would depend on simple climatic factors, of temperature and humidity, rather than on some of the more complex factors which determine the distribution of other species of anopheles. Although the hibernation of gambiae has not been recorded, nor have its eggs been kept alive more than a few weeks, the possibility of gambiae-transmitted outbreaks due to annual spring importations of the species in areas where winters are severe and summers are short must be taken into consideration since the transmission of malaria may rapidly become intense following the introduction of gambiae.

An idea of the final range of gambiae in America may be obtained by comparing the climatic conditions of those parts of Africa from which gambiae has been reported (Fig. 75) with those of different parts of the Americas.

From an analysis of the meteorological conditions under which gambiae is found in Africa, it may be seen that conditions in the New World, from the northern provinces of the Argentine Republic through all the South and Central American countries and the West Indies and even to the southern section of the United States along the Gulf of Mexico and the Caribbean, are favorable for gambiae breeding.

There will, of course, be those who will argue that the apparent

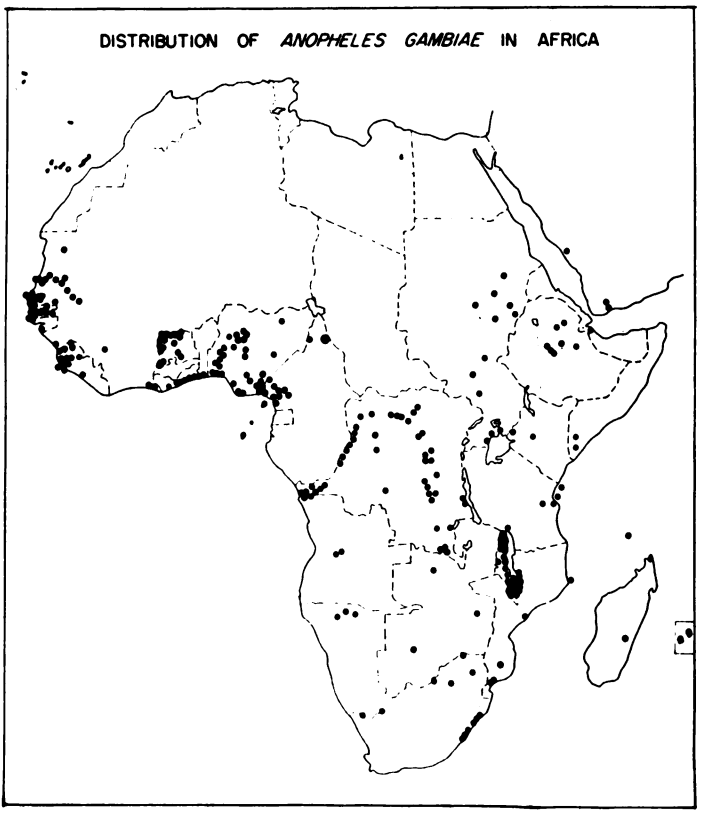

FIG. 75.

adaptation of gambiae to life in Brazil away from its normal habitat was always precarious at best and that its disappearance following control measures simply proves its failure to adapt itself and is an indication that its presence in Brazil was of little importance to the rest of the continent. The same persons will be ready to insist that the disappearance of gambiae was mainly because of biological factors rather than the result of control measures devised by man.

However, observers in Brazil are agreed that gambiae was thoroughly at home in the new faunal region. The eight months' dry season in the invaded region was a myth during 1939-40, when a more than usual amount of rain fell with a prolonged distribution throughout the year, especially in 1939 (Tables 3-5). The occasional year-long droughts which occur in much of the area infested with gambiae did not materialize even though the people of such regions prayed for a drought year, or even two, rather than a repetition of the 1938 outbreak of gambiae-transmitted malaria. But this could have brought but temporary relief, gambiae having demonstrated its resistance early in its Brazilian career by weathering the severe drought of 1932.

Those who had the opportunity to observe gambiae in Ceará and Rio Grande do Norte from 1938 to 1940 have no doubt but that this species, unchecked, would have maintained itself indefinitely in Brazil and would eventually have become a scourge throughout the Americas. They point out that the biological factors responsible for the decline and disappearance of gambiae in Brazil, but not present previous to 1939, were Paris green and pyrethrum.

OPINIONS ON SPECIES ERADICATION BEFORE SUCCESS OF CAMPAIGN

Although in retrospect it is easy to say that gambiae could have been rapidly eliminated from Brazil at a minimal cost had a well-oriented attack been made on the species at the time of its discovery in 1930, at no time from 1930 to 1938, and even in 1939,

was it possible to get serious encouragement on the possibility of species eradication from those experienced in antianopheles work. In 1930 those who argued that although *A. gambiae* had crossed the ocean and established itself in Brazil, it would not be able to survive indefinitely in this new faunal region, were the first to argue that if it did survive in America, there was no hope of chasing down the last of this or any other species, and eradicating it. When, early in 1931,[1] gambiae was found in the interior of Rio Grande do Norte, the problem was regarded as hopeless from the standpoint of an eradication campaign (Soper 1931), but in 1932 it was thought that the drought of that year might accomplish what man could never do. This hope was vain and in 1933 and 1934 when it was found that gambiae had weathered the drought successfully, no steps were taken to eradicate it.

The fact that gambiae was known to have spread 182 kilometers during its first year in Brazil, led naturally to the suggestion that perhaps it had even gone much farther without its presence having been detected. The logical question raised was what hope there might be of erecting an efficient local barrier against the farther spread of a mosquito which had crossed successfully the 1,680 mile salt-water barrier of the South Atlantic.

Recourse to the works of the masters failed utterly to provide inspiration for any attempt to eradicate gambiae from Brazil, as the following excerpts show:

> No one has ever supposed it possible to exterminate mosquitoes from whole continents, or even from large rural areas. The operation must be confined principally to towns and suburbs. No one imagines that it will be possible to exterminate every mosquito even from towns—we aim only at reducing their numbers as much as possible (R. Ross 1901).

> The idea that vast tracts peopled only with natives, could be freed from any mosquito is too silly to require any disclaimer (——, 1923).

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[1] Davis on receipt of Shannon's report, December 1930, that *A. gambiae* had spread since May over an area of only some six square kilometers, replied under date of January 7, 1931: "Eradication would appear to be hopeless now." Seven months later E. R. Rickard on learning that *A. gambiae* had been found at São Bento, 182 kilometers from Natal, wrote, "This certainly looks serious and greatly diminishes any possibility of species extinction."

The work described in the first edition of this book recorded a new phase in antimalarial work, namely the control of malaria by anopheline reduction in rural areas.

. . . The radical method of mosquito reduction has everywhere given results superior to any other.

"Drainage and reduction of breeding areas is the all-important work in the antimalaria campaign" was the conclusion reached in Panama; and it confirmed my own views.

Consequently, although *A. costalis* (gambiae) can be destroyed by open drainage, to eradicate malaria in Africa would require a more thorough drainage and upkeep than is necessary on the flat land of Malaya where mosquitoes like *A. kawari* and *A. umbrosus* are the carriers (Watson 1921).

Only MacGregor who made a survey of Mauritius in 1924 was found to be so bold as to advocate eradication of gambiae:

For this reason there is every likelihood of exterminating the species rapidly from the central parts of Mauritius down to an altitude of 600 feet if the comparatively small number of breeding places in the inland districts are destroyed. Below 600 feet the species can be successfully exterminated also in the course of time, I believe, once the efforts of the anti-malaria campaign in Mauritius are systematized so that the anti-malaria measures are carried out thoroughly, section by section, until at last the whole island has been dealt with.

In August 1938 a letter was written by one of us (F.L.S.) to Park Ross, whose work of controlling gambiae-produced malaria by disinsectization of houses had been visited in 1935:

We . . . are beginning to consider the possibility of doing something about gambiae. This mosquito is apparently limited to regions where a great reduction in rainfall occurs during certain months of the year and where conditions enable us to dream of complete extinction of the mosquito from the continent. I say *dream* because I realize what many will think. I would appreciate very much getting your opinion as to whether with adequate funds and men you could clear gambiae entirely from a known limited area of infestation.

Under date of October 9, Park Ross replied:

It is not possible to give emphatic opinions because we do not know your terrain. We have no notion as to permanent rivers, perennial swamps, or whether your dry season is in cold weather as ours is, but seeing you know the terrain here, a few statements relating to it may be of service to you even if they may not be orthodox.

A.—Winter control of breeding appears to us to be the key to the situation. In the Table Mountain area (Valley of a Thousand Hills) gambiae were not found for three years. There was no winter control. This year breeding again occurred in relatively small numbers. We did hut spraying only.

In the Mandini area of Zululand (which you know) we have now kept up winter control by spraying breeding places for some years. Funestus has now been absent for the same time. Until we had winter control, fever had never been absent from the area, at least not for 50 years. The summer incidence of gambiae used to average 200-300 adults per hut. It has now dropped to a summer average of two to three per hut and that mainly in the vicinity of uncontrollable streams. We are sure that had it not been for these streams we could have got 100% control by our winter measures plus summer adult work.

B.—Our large perennial rivers, such as the Tugela, most certainly act as focal points. They provide good breeding places for gambiae during winter in seepages and laterals. In summer, owing to floods, they are not so difficult to handle. We cannot, with our staff, get 100 per cent winter control.

C.—The fact that gambiae larvae are usually found in certain favoured situations does not mean that eggs are laid exclusively there. The hatch may be dependent on favourable conditions of water, environment, etc., and not on selective laying on the part of the mosquito. . . .

Around perennial swamps, as soon as temperature conditions become favourable and cattle create suitable breeding puddles, there is, with us, immediate breeding in these puddles. This makes one surmise that limited breeding is taking place in the more permanent water all the time, even if larvae may be almost impossible to find.

D.—We have proved that adults are not only easily carried by cars but they readily reinfect an area. Unless you control car traffic from an infected area into a sprayed area, reinfestation is bound to occur. . . .

One hundred per cent success by spraying will depend on your terrain and men.

It is clear from a careful reading of the above paragraphs from Park Ross's letter that he believed the problem to be essentially an administrative one. In 1938, at the time plans were being made for the organization of the Malaria Service of the Northeast, the only persons who seriously considered the possibility of the eradication of gambiae from Brazil were those familiar with the work of the Yellow Fever Service in the eradication of *Aedes aegypti* from many parts of Brazil, beginning about 1932 (Soper 1938; Soper and Wilson, 1942).

Previous to 1930 yellow fever campaigns were based on the reduction rather than the eradication of the urban mosquito vec-

tor, since it had been shown that a considerable density of aegypti is required to keep yellow fever virus in circulation and that the disease generally disappears long before the extinction of its vector. Such disappearance of recognized yellow fever occurred not only in the larger centers of population, where the density of the vector was reduced, but also throughout entire tributary areas. Under these circumstances, it was logical to organize temporary anti-mosquito services to eliminate yellow fever simultaneously from all of the larger centers of the endemic regions and thus terminate the threat of yellow fever forever. Unfortunately this program was shown to be untenable when yellow fever blossomed out as a jungle disease (Soper, *et al.*, 1933) not susceptible to control by antimosquito measures. The development of methods rendering possible the species eradication of *A. aegypti* went unnoted except by those working with the problem at a time when the discovery of jungle yellow fever and new methods of vaccination were attracting universal interest. Shannon who had made a detailed study of *A. aegypti* breeding in the city of Salvador, Baía, in 1929-30, previous to the introduction of the modifications in method which made the local eradication of this species possible, revisited Salvador and personally verified the absence of aegypti breeding in 1936, becoming enthusiastic over the administrative work of the Yellow Fever Service. This enthusiasm was the basis for Shannon's opinion openly expressed in November 1938, that the eradication of gambiae from the State of Ceará was within the possibilities of the administrative technique of the Yellow Fever Service.

In spite of this favorable opinion it should be stated here that the Directors of the Yellow Fever Service themselves were far from convinced. While it was known that certain individual breeding areas could be cleaned of larvae and that adults could be killed in the houses with spray insecticide, it was by no means certain that the entire infested region could be cleared of gambiae with the funds which might become available before the infested area became so extensive that all thought of eradication would have to be abandoned. And so it was that the Yellow Fever Service undertook the solution of the problem of gambiae eradication rather as a moral obligation than as a reasonable program with fair chances of success. It was recognized that new administrative techniques

would have to be developed and the principal incentive to faith in the possibility of such successful development was the foreknowledge of the dire results of failure to eradicate gambiae before the problem became further complicated by extension to other regions (Soper 1938). Excerpts from the letter of November 28, 1938, in which the project was recommended to The Rockefeller Foundation for approval show this clearly:

I am enclosing herewith Shannon's seven page report on conditions in Ceará as noted in his work up to the 17th of this month. . . . I find it impossible to be as optimistic about final results at as early a date as is Shannon but cannot force myself to be entirely pessimistic as to final results if we are able to avoid the spread to the Parnaíba and São Francisco River valleys. The amount of work to be done in the areas already infested and threatened is enormous; whether final eradication is possible or not, I believe the effort will justify the expense in the actual reduction of malaria in the region during the time that operations are carried out. The most hopeful factor in the whole situation is the small proportion of the total infested area which is capable of year round breeding of any mosquito. . . .

With the present extension of gambiae I feel that any failure to take immediate steps would be criminal if means can be made available for immediate action. . . .

There can be no doubt that we are asking for an enormous headache for quite some time in offering to organize this program but I see no way to avoid the issue. And if work is going to be done it must be done on as large a scale as possible from the beginning. . . .

No one foresaw the relative ease and rapidity with which gambiae might be eradicated,[1] estimates running as high as ten years'

[1] At present it (gambiae) is still limited to an area from which eradication will not be impossible and where control is perfectly practicable.

It is a mosquito of extraordinary resistance and adaptability, breeding easily under the meteorological conditions of the Northeast, and it will only with difficulty be eradicated from its new habitat.

Only years on end of unrelenting systematic campaigns, of vigilance and isolation of the infested region, will remove and annul the enemy (E. Chagas, 1938).

If gambiae reaches neither the São Francisco River or Parnaíba during the next rainy season it would appear highly probable that it can be exterminated, *at least in the State of Ceará* (Shannon. Unpublished Survey Report, 1938).

Dr. Lessa Andrade who had worked on the control of malaria at Natal and Macaíba, gave it as his opinion in November 1938 that under conditions existing in Rio Grande do Norte it should be possible to get rid of gambiae within five years, if the necessary men and money were provided and if the State could be *protected against reinfestation from Ceará* (Personal communication).

time and ten million dollars. It is interesting to note that the time and money spent in the eradication of the Mediterranean fruit fly in Florida, 1929-30, were also far less than the original estimates: Congress, facing requests for appropriations of nearly twenty million dollars, made $8,780,000 available, of which less than six million were spent; eradication of the fly did not require several years as anticipated, but was accomplished in sixteen months (United States Department of Agriculture, 1929, 1930, 1931).

Only after several months' work and the expenditure of large sums of money did those in charge of the Malaria Service of the Northeast dare to believe that the eradication of gambiae was possible. Just at this time Corradetti (1940) was writing that malaria in the presence of gambiae could not be eliminated, but control might be attempted with screens, quinine prophylaxis, and treatment. Barber (1940), who was in the infested region from May to August, 1939, was hopeful regarding the temporary limitation of gambiae's range but frankly pessimistic as to species eradication. Barber believed the people would have to adapt themselves to living in so highly malarious a region and advised education as to methods for making the homes mosquito proof through the use of homespun cotton netting:

> We often demonstrated to them the cause of their trouble, showing them gambiae caught in their dwellings . . . the beginning of an education which may take a generation or two to accomplish.
>
> If it is no longer possible to extirpate gambiae in Brazil, its spread to large up-river and up-coast regions may be prevented or delayed for many years.

GROWTH OF FAITH IN SPECIES ERADICATION

In addition to the data on the speed of cleaning individual places (Table 22), it is interesting to see in retrospect how those responsible for the work gained increasing confidence as the campaign progressed. This can best be done through quoting from the *President's Review, 1939,* of The Rockefeller Foundation which gives the attitude as of the end of that year, and from correspondence between the field staff (F.L.S.) and the New York Office (W. A. Sawyer) of the Foundation throughout the year 1940.

The following cautious prophecy was made in the *President's Review* of the work of the Foundation for 1939:

If the mosquito can be held within its present limits during the wet season of 1940, we can begin to think of the possibility of its eventual eradication from the entire region. This, of course, would mean extermination of the last surviving pair. It must be admitted that eradication is a rash word in terms of prophecy.

On February 9, 1940, after a trip through the State of Rio Grande do Norte, the report (F.L.S) to the New York Office included:

I arrived at Mossoró, Rio Grande do Norte, on January 26th and spent the following days until the 31st with Doctors Hackett and Wilson looking over the gambiae situation in the State of Rio Grande do Norte and discussing the situation in Ceará as well. . . . I was surprised to find Dr. Hackett somewhat more optimistic than I had ever permitted myself to become regarding the rapidity with which results can be obtained in much of the infested area. On the other hand, I found him more pessimistic regarding the final clean up of certain difficult areas. I have felt, and still do, that if it were possible to prevent the spread of gambiae to regions other than those already known to be infested, the final elimination would depend only on having adequate funds and efficient administration. . . .

The Service is now facing the first real test of its work with the onset of this year's rains. Both Wilson and I feel that the rains will disclose any defects in the organization which are not now apparent; but that, on the other hand, many places will fail to produce gambiae this year which had serious outbreaks of gambiae-transmitted malaria last year. We are even hoping that a mistake has been made and that the Malaria Service is greatly overstocked with drugs for treatment of malaria this year. . . .[1]

On April 11, growing optimism was reflected in the report of another visit to the infested area:

Dr. Wilson and I arrived back in Fortaleza yesterday after a week in the Jaguaribe River valley during which we traveled a total of some six to seven hundred miles and visited the laboratory at Aracatí and the administrative centers at Russas, Jaguaribe, Icó, and Iguatú. . . .

The rains around Aracatí have been heavier this year than last and the region has also suffered more from the flood waters of the Jaguaribe River, since

[1] This proved to be true and the inventory at the end of the year contained the following items: Quinine, 1,328,625 tablets (0.25 gm.); atabrin, 1,427,235 tablets (0.1 gm.).

excess water has fallen throughout the valley. In spite of the extremely favorable breeding conditions, Aracatí itself, and much of the surrounding region, is free of gambiae. . . . That this absence of gambiae from large areas is due to control measures is indicated by the way in which gambiae has increased rapidly during the past two months at Cumbe, the near-by study area where control measures are not being taken. The absence of gambiae is further attested to by the great reduction in malaria this year. . . .

At Russas, which is the headquarters for the lower Jaguaribe valley, I was truly surprised to find Dr. Gastão Cesar de Andrade so apologetic for the continued existence of a number of dirty spots in his division. We have all recognized this lower Jaguaribe as probably the most difficult problem to be solved with regard to gambiae in Brazil, and, when the heat was on us last year, we drained it of trained men repeatedly, feeling that the frontier had to be protected at all costs. And so it was that this division did not really have a chance to get organized until well toward the end of the year. Even so, some parts of the division are remarkably clean, and none of them are as they were last year, with the exception of Gracismões which is a study area under the direction of the group from the Oswaldo Cruz Institute working under the direction of Dr. Evandro Chagas. In checking over the results of house captures it was interesting to note that the dirtiest places in the entire division were those contiguous to the uncontrolled Gracismões area. Our Service has been fumigating all the houses in the contiguous areas since January, but even so the number of mosquitoes to be found is many times higher than in other parts of the division. (I sent a wire to Dr. Chagas yesterday requesting his acquiescence to the organization of antilarval and fumigation services throughout the Gracismões area). . . .

In the Jaguaribe Division which extends from just above Limoeiro up the river to Bebedouro, we found Dr. Severo claiming complete lack of evidence of gambiae except for a distance of twelve kilometers along the river above the junction with the Russas Division not far from Limoeiro.

In the Icó Division we found Drs. Oswaldo Silva and Jefferson de Souza both quite optimistic regarding the future, with known foci of gambiae infestation at only a few points—viz., a small area just west of Lavras, two isolated points on the Riacho dos Bravos just south of Cariús, and a rather large area at Barroso on the Jaguaribe River, thirty-six kilometers down stream from Iguatú. Both of these men know from experience that once they have found a focus of gambiae infestation in this region they can get rid of it with present methods, and both have undertaken to have no gambiae in their division during the month of June 1940.[1]

We did not visit either the Quixadá or Cascavel Divisions, both of which

[1] This promise was fulfilled in both cases.

have failed to report gambiae for some time now. It is entirely possible that these divisions are really clean at the present time.[1]

With all my optimism of the November and January visits, I did not expect to find things as satisfactory as they are at the present time. Gambiae has increased most markedly in Cumbe and Gracismões where no control measures have been applied, but elsewhere it has been held in check much better than was to have been foreseen. Except in certain very limited areas malaria is not a serious problem this year, and in most places our own personnel is not taking preventive treatment. No problems have been found which are considered insoluble by the men responsible for solving them. Difficulties there are, of course, and much remains to be done, but everyone is now satisfied that with present measures, adequate funds, and a little time, the problem of gambiae in Northeast Brazil can be solved.

By July 10 confidence in the antigambiae measures adopted had grown to such proportions that definite expectations of gambiae eradication were expressed:

The rapidity with which a place can be cleaned of gambiae in this part of the world with present technique is almost incredible. Cumbe, a rural area close to the laboratory, was reserved for many months for laboratory studies and no control measures were undertaken there until April 29th, 1939. During the third week of April, laboratory workers caught with hand tubes 800 gambiae in the houses of Cumbe and, in the days just before control measures were applied, division capture squads, working with insecticide, caught over 2,200 gambiae. Control work consisted of Paris green and house fumigation twice a week. The last larvae were found on May 15th and the last adults during the last week of May!

I fully believe that all visible infestation with gambiae will be exhausted before the end of September, possibly before the end of August, and that by the end of the year we will be justified in reducing the Service to one of skeleton proportions to search for dirty spots and for unexpected reappearance both within the previously known infested region and outside the region.

I am authorizing reducing the Quixadá service to a sentinel service on a monthly cycle and having the cycle for Jaguaribe changed from 15 to 30 days.

By September 3, the situation was so favorable that the suggestion was made that the budget for the following year be reduced:

I have just returned from a two weeks' trip through the gambiae areas of Brazil and as result am wiring you,

"Request one hundred thousand gambiae budget 1941 Soper."

[1] Cascavel has not been again found infested, nor has the Quixadá Division itself although frontier infestation was found at Madalena six months later.

This reduction of $150,000 in the amount requested from The Rockefeller Foundation for 1940 is only a partial measure of my present optimism since I very much doubt that it will be necessary to spend all of this amount. However, there is so much at stake and so much already invested in this program that ample provision should be made for all possibilities of unexpected reaction on the part of the fast disappearing gambiae.

I left Fortaleza on the morning of August 19 in the military air-mapping plane which has been working with the gambiae service in mapping the lower Jaguaribe valley. We flew down close to Caponga, the closest point to Fortaleza at which gambiae has been found, and then went over Cascavel and followed the highway from Boqueirão to Russas. At Russas we came down to a few hundred meters and flew over the study area, one of the last points of gambiae resistance in this State. Then up the river to Limoeiro and a short distance up the Banabuiú River before turning back and covering the Jaguaribe River between Peixe Gordo and Aracatí. The flight was a most interesting one and gave me the proper background for an optimistic week in the region in which gambiae production has fallen so markedly during the past few months. As I got out of the plane at Aracatí I fully realized for the first time that the gambiae mosquito in Brazil is doomed to extermination, not at some shadowy time in the uncertain future, but here and now. The reduction which has occurred in the breeding in the lower Jaguaribe, as well as elsewhere throughout the region during the past few months, has taken place in spite of an exceptionally wet and prolonged rainy season!

I remained with Causey at the laboratory a couple of days but refused to get excited over the fact that he had recently shown that gambiae eggs can be kept in wet sand for 25 days and still produce larvae; careful checking of the Icó district where control of larval production was abandoned in April has failed to reveal any persistence of gambiae beyond the period routinely used before discontinuation of control measures.

On the 21st of August I went with Dr. Paulo Antunes to Assú in Rio Grande do Norte. Here we found Dr. Bustamante getting ready to drop control measures to give gambiae a chance to show its presence; no gambiae have been found in the Assú Division since March. The work in Rio Grande do Norte has not been organized in such a thorough way as it has been in Ceará, but even so it is quite probable that gambiae is already absent from the Assú Division. . . .[1]

While in Rio Grande do Norte we went to the Division of Ceará Mirím where we found much to criticize in the organization of the work in spite of which we came away willing to believe that gambiae is absent from the area or is continuing only in small areas of low production where eradication

[1] No further production of gambiae was found.

should follow discovery rapidly.[1] This entire region has given only a few scattered positive findings this year with less than 100 adults and less than 100 larvae found since the first of January. However, we are taking no chances on the area; it will be air-mapped this week and we are throwing a large number of trained men from Ceará into the division to find out if gambiae is still present or not and to get rid of it if found.

From Natal we returned to Russas. . . . Here, to the surprise of many, only one adult gambiae was found during the month of August. From Russas we drove up to Jaguaribe and Icó where all control measures have been taken off and gambiae let breed at will. There is a monthly check on both adult and larval findings throughout the once infested areas now believed to be clean. In Icó the discontinuance of Paris green was followed by a great increase of Nyssorhynchus production. The field inspector is not expected to recognize the difference between gambiae and Nyssorhynchus larvae and is responsible only for collecting samples from all foci found and sending them in to the laboratory of the post. In the Icó laboratory seven microscopists are at work, each with his helper to prepare slides, whereas in Jaguaribe there are only four microscopists. Up to 35,000 larvae are examined daily in the two laboratories. After seeing this machine at work one cannot avoid a certain confidence in the negative reports from these areas.

On the way back from Jaguaribe we stopped once more at Russas and got the final results for the month of August. Only two of the four sectors of the Russas Division—viz., Russas and União, showed adults or larvae during the month, and the number of places infested was minimal in comparison with previous months. During May the Russas Division had 226 dirty points, during June 126, during July 103 and during August only 30. Also the density of infestation in the dirty spots was very low; of the places found with gambiae during the month, several which were dirty at the beginning of the month, were examined once more during the past week and are now clean.

The Aracatí sector was clean in August so Antunes and I drove to Aracatí and helped Causey eliminate the laboratory colony (August 31, 1940).

During the last days of the trip we were forced to realize that summer has at last begun and with clear skies and hot winds a standing order for the next four or five months, there would seem to be no reason for letting any gambiae infestation *which can be found,* be carried over into the next wet season. With the possibility of discontinuing antilarval measures in all areas well before the end of the dry season and giving gambiae a free hand to declare itself, there seems to be little chance for gambaie to exist in any suspected region without being found.

Please don't get the idea that I will be ready to declare gambiae absent from

[1] No further production of gambiae was found.

Brazil at any time in the near future. However, I do believe that we are entering now on the second phase of the campaign during which a great deal of watchful waiting must be done before vigilance can be relaxed (Icó, Quixadá, and Jaguaribe are already in this phase of the campaign).

I did not mention it above but instructions were given during the past 15 days to discontinue all treatment throughout the gambiae area. There are still some cases of malaria but not enough to justify keeping special employees to treat the few cases which do appear.

Of course I do not expect you to believe that the situation is as rosy as I have painted it above. . . .

But a month later (October 3) the report read:

. . . During the early days of September some gambiae breeding was found but during the past three weeks no adults, or larvae, have been discovered by the Malaria Service of the Northeast. During the entire month of September, six foci of gambiae larvae were found: one in Araújos, one in Patos, one in Pedro Ribeiro, and three in Timbaúbas. Araújos and Timbaúbas are villages included in the Chagas study area where we took over control late, and Patos and Pedro Ribeiro are neighboring villages. During the month of September only one adult gambiae was found in Brazil: at Jurema, a village lying between Russas and União not very far from the points at which larval foci were found. . . .

On November 8 announcement was made that control measures had been suspended except in a very limited area and that the happy results obtained with gambiae in Brazil were stimulating visions of similar victories over both gambiae and other anopheles in other parts of the world:

In April 1940 at the height of the rainy season both antilarval and anti-adult measures were discontinued in a large part of the Icó Division which had been at one time heavily infested but had been apparently clean for some time. After a considerable period of time during which gambiae did not again appear in this area, the other areas believed to be free of gambiae were put to the test of discontinuing all control measures. To date no area has been found reinfested where work has been discontinued in this manner. I have officially authorized the discontinuation of all control measures throughout the Russas Division except in a very limited area where gambiae was found in August. All control measures have already been discontinued in all of the other divisions. (As you know, a small infested area has been found outside the previous limits of the Quixadá Division in an area which was never worked and never suspected. This area is cleaning up rapidly and in and of itself is of very little importance.)

I really believe that we have come to the point with gambiae in Brazil where it is now only a matter of "mopping up," that is, searching out all possible missed foci[1] very few of which should be found outside of the area of operation and probably none inside this area.

My attention has recently been called to Dr. Boyd's address of last year in which he suggests that malaria control should be based on long-term operations with gradual results rather than on blitzkrieg methods. I believe this attitude is becoming general among malariologists. . . . In most cases this may well be the logical program, but I am wondering if there are not many special malaria problems which can be best attacked by methods similar to those used with gambiae in Brazil. For example, I am thinking of the malaria problem of the Pacific Coast of Peru. This area is separated from the Amazon valley by the high range of mountains over which anopheles probably pass very rarely so that reinfestation from this region would probably not occur. The Pacific Coast malaria problem is naturally linked with the river valleys but these river valleys are comparatively short and separated from each other by stretches of desert. I believe it would be entirely feasible to attempt the elimination of *A. pseudopunctipennis*[2] from these valleys one at a time with the expectation that only at rare intervals would reinfestation occur either over the Andes or from neighboring valleys. In a comparatively few years it should be possible to get rid of all malaria on the coast of Peru through the complete elimination of the species. Once eliminated, an occasional survey at regular intervals should be made to discover any reinfestation and eliminate it before it becomes of any size. Once the original work is done the upkeep should be very low.

In the light of what has already been done in Brazil I believe that a total species elimination campaign would be highly efficient in that part of the Anglo-Egyptian Sudan about Khartoum where gambiae breeding is an important problem along the River Nile and in the irrigation system. . . .

In Africa there must be many places where gambiae has a precarious existence during at least part of each year and from which it would be relatively easy to exclude this species if it were once eliminated. Even in that part of South Africa where Park Ross has been working it would probably be good business to spend enough to get rid of gambiae and then work only a frontier zone next to the unworked infested area.

And of course, once one starts to let his imagination go he cannot avoid considering the many islands where malaria is a serious problem which are limited geographical units with a definite area to be cleaned and with some

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[1] None have been found.

[2] Possibility of eradication of *A. pseudopunctipennis* in Peru had been previously suggested by Shannon (1930).

natural protection against reinfestation. Small islands such as Mauritius and Granada may lead one eventually to attack such problems as *A. culicifacies* in Ceylon. . . .

HAS GAMBIAE BEEN COMPLETELY ELIMINATED FROM BRAZIL?

While admitting the inferiority of negative to positive findings, it must be recognized that negative findings for gambiae should be given a very high rating, because:

the adult is prone to enter houses and its presence in the community is easily established by house captures;

the larva occurs predominantly in the most simple and accessible type of breeding place, and

the presence of the species in an area for even short periods generally results in an explosion of malaria;[1]

the value of negative findings was probably somewhat increased by the offer in January 1941 of approximately ten days' salary as a premium to any inspector finding gambiae; in July this premium was increased to twenty days' pay but without result.

It now seems reasonably safe to state that gambiae no longer exists in the previously known infested regions of Northeast Brazil nor in the neighboring districts of Ceará and Rio Grande do Norte, nor in the States of Paraíba, Pernambuco, Alagôas, and Piauí.

This statement is based on the following evidence:

continued search for the species in all previously infested areas for periods ranging from one to two years after the interruption of all control measures;

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[1] However this does not always occur and gambiae can remain for a considerable time in areas where there are no gametocyte carriers without causing an outbreak. At Madalena, the last point found infested in October 1940, there is reason to believe that gambiae had been present for a year or longer without anything happening to call attention to its presence. This can be attributed to the small number of carriers in this area which is not favorable to malaria transmitted by local anopheles, and to the fact that one of the partners owning the property knew of the serious outbreaks of malaria in the Jaguaribe valley and as a matter of precaution gave orders that everyone on the property coming down with fever should be removed immediately.

since no measures of a permanent character were used in the campaign against gambiae, the infested region remained as suitable as ever for gambiae production so that the discontinuation of control was an open invitation to gambiae to resume breeding;

repeated search for the species in the surrounding regions;

anopheles surveys at more distant points;

absence of malaria in regions which had severe malaria during the period of gambiae infestation, and failure to find gambiae in areas which have recently reported outbreaks of malaria.

The maps on pages 147, 148, and 151 show the type and distribution of but a part of the negative evidence against the persistence of gambiae in Northeast Brazil.

SELECTIVE SPECIES ERADICATION

Although Anopheles of the Nyssorhynchus group found in the gambiae infested areas are highly susceptible to both weapons used by the Malaria Service, Paris green and insecticide, this susceptibility becomes operative only in case of direct attack. While it is true that the measures taken greatly reduced the density of Nyssorhynchus in the areas worked, the results were never so complete as those observed with gambiae, and the production of Nyssorhynchus rapidly returned to normal once control measures were abandoned.

The very characteristics of gambiae's biology which made its spread in Brazil possible and made it so much more effective as a transmitter of malaria than are the native anopheles, also made gambiae more vulnerable to Paris green and insecticide than are the latter. The preference of the gambiae larvae for shallow sunlit pools without vegetation, makes it very susceptible to attack by Paris green; while gambiae's innate desire for shelter in human dwellings makes it easily discoverable and susceptible to attack with spray insecticide.

Various species of Nyssorhynchus, on the other hand, breed in a much greater variety of places: in much less exposed waters, in the midst of vegetation, in the shade, in the center of pools, in

deep water, all of which are much less easily treated with Paris green. Furthermore, only a small percentage of Nyssorhynchus is to be found indoors, making these species much less accessible to insecticide than is gambiae.

Although Nyssorhynchus has just been discussed as a unit, as a matter of fact there are wide differences in the breeding habits and domesticity of different species of this subgenus. Any future attempts at eradication of anopheles in Brazil should be based on careful selection of the individual species to be attacked, rather than on a general campaign against all anopheles. After it was reasonably certain that gambiae no longer existed in the region, an attempt was made to eradicate all anopheles from the test area at Cumbe. The results of this attempt indicate that, given the men, money, and necessary materials, there is nothing basically impossible about the eradication of various species of the Nyssorhynchus subgenus.

DANGER OF REINFESTATION FROM AFRICA

While there may be some hidden focus of gambiae infestation still present in Brazil, it seems much more probable that any future finding of gambiae in this country should be attributed to future air traffic between Africa and America. That there is great danger of reinfestation was shown by the finding of a female gambiae on a plane arriving in Natal on October 9, 1941; on January 8 and 10, on May 17 and 26, and on June 15 and 23, 1942, additional specimens of gambiae were found on planes arriving from Africa. Those found in January were somewhat damaged and had apparently been killed by disinsectization in flight but those found in May had probably arrived in Natal alive. Permanent vigilance over all types of aircraft is necessary and, in addition, gambiae surveys should be made at frequent intervals in areas subject to reinfestation from Africa. Gambiae, rather than anopheles, surveys are suggested, since the native anopheles are only slightly domestic; gambiae surveys could be most easily and cheaply made by the Yellow Fever Service which makes house searches for *Aedes aegypti* infestation as part of its routine work.

Should gambiae once more invade Brazil or should it be found to have already extended its range beyond the regions investigated by the Malaria Service of the Northeast, there now exist a technique and the personnel trained in that technique whereby a repetition of the tragedy of Northeast Brazil during the 1930's can be avoided.

PREVENTION OF TRANSFER OF DANGEROUS ARTHROPODS

The serious problem created in Brazil by the introduction of *Anopheles gambiae* in 1930, even though such introduction almost certainly occurred by boat rather than by plane, first called the attention of health officers to the serious problem of preventing the transfer of disease vectors from one region to another by the fast-developing air traffic of the world. Although, in the case of gambiae, the danger was due to the introduction of an efficient vector in an area where the disease already existed, it was recognized that the introduction of a disease itself in a region already well supplied with vectors but free of the disease in question might be brought about by the carrying of infected vectors by air traffic.

Especially was the question raised of the possibility of yellow fever being carried through the transfer of infected *Aedes aegypti* to regions where the vector was present in large numbers, but where the disease was absent. The threat of summer epidemics hangs over such temperate zones as the southern United States, where *A. aegypti* is permitted to breed unrestrained, and the more terrible threat of permanent yellow fever endemicity casts a shadow over India and the Orient, should the virus of yellow fever ever reach those regions from Africa.

Considerable work has been done on the air transportation of arthropods (Griffitts and Griffitts 1931, Symes 1936, Williams 1935 and 1940, Park Ross 1938, Mackie and Crabtree 1938, Welch 1939, Wiseman, *et al.* 1939, Whitfield 1940) and on methods of disinsectization of planes, but there has been no development of a universal consciousness of the threat that modern air transporta-

tion represents, especially in wartime when long-distance unannounced flights of large numbers of planes are the rule rather than the exception, through the transplantation of arthropods dangerous as vectors of human and animal disease and as agricultural pests. The problem of preventing the reinfestation of the American continent by gambiae imported from Africa is only one small phase of the more general problems of preventing the extension of the range of gambiae in any direction from its present habitat and of protecting every region of the world from the pests and diseases of every other region.

The experience of the Malaria Service of the Northeast in the disinsectization of planes arriving in Brazil from Africa has only served to emphasize the dangers of international air traffic and the difficulty of obviating this threat. As already stated, *Anopheles gambiae* has been recorded seven times, *Glossina palpalis* twice, and other arthropods whose possible importance has not been studied, many times (Table 18).

Disinsectization of the large modern commercial and military planes is not easy and requires motorized equipment for its rapid execution. Great difficulty has been found in preventing the entrance of local insects into planes before disinsectization has been made upon arrival and after final disinsectization has been carried out on planes bound for Africa.[1] It is becoming increasingly clear, as experience accumulates, that disinsectization should be routine and should be carried out immediately before departure and repeated during flight. In the absence of compressed-air lines to different parts of the planes and to avoid carrying unnecessary weight, pyrethrum in much heavier concentrations than usual should be used in flight. Some efficient method of complete disinsectization in flight which will not involve carrying additional weighty equipment is urgently needed. Careful search of planes for living arthropods at the port of arrival, with adequate penalties if found, may be expected to secure satisfactory disinsectization before departure and during flight and eventually, the development

[1] The Malaria Service of the Northeast has assumed the responsibility of attempting to prevent the infestation of Africa with American arthropods through disinsectization of planes before departure.

of planes so constructed and equipped as to facilitate the prevention of arthropod transportation.

Under present conditions, however, it is probably more practical for the health officers of each region to assume the risk of possible debarkation of invading arthropods in the first minute or two after arrival of planes and limit their activities to routine disinsectization with motorized equipment immediately after the passengers and crew have left the plane but before baggage, mail, or anything else has been taken off. In Brazil, the Malaria Service of the Northeast insists on disinsectization of planes coming from Africa before either passengers or crew leave the plane.

The problem is one which merits the closest attention of health and military authorities in all parts of the world.

WILL BRAZILIAN ANTIGAMBIAE MEASURES SUCCEED IN AFRICA?

Now that gambiae has apparently been eliminated from Brazil, there are those who are willing to attribute its disappearance in large part to climatic and other factors rather than to Paris green and insecticide. While it is true that conditions in Northeast Brazil favor a program of eradication, it is just as true that any localized attempt to protect individual towns and villages from malaria transmitted by gambiae would have resulted in the permanence of the species in the region and its farther spread. It is also true that within the infested regions were various areas where conditions were highly favorable to gambiae throughout the year, as at Cumbe, but that the method of attack evolved cleaned it out rapidly.

On the other hand, it must be admitted that until the attempt is made to apply this eradication technique to gambiae in Africa, no one can predict with certainty the outcome of such application. It has been shown that the gambiae larva is very susceptible to Paris green, and the adult to attack with insecticide. There exist large areas in Africa seriously handicapped by gambiae-transmitted malaria in which conditions for permanence of the species are no more favorable than are those in many parts of

Northeast Brazil. In other areas gambiae exists only because irrigation water is available for breeding. Where unfavorable conditions exist throughout an area large enough to justify the expense of eradication and the permanent maintenance of a frontier barrier zone, eradication should, in spite of the original cost, prove to be a highly profitable investment. For example, Symes' exposition of the malaria problem at Nairobi (1940) and of the cost of malaria to the community there gives the impression that the gambiae mosquito in this area could be eradicated with methods used to good advantage in Brazil:

> There are, of course, great variations in seasonal and local densities of these species. . . . *Anopheles gambiae* is the most notorious from this point of view. During the drier months it is absent, as far as can be ascertained, from all but a few permanent breeding places: the Nairobi River and irrigation canals in the swamp area, the Ngong River below the Prison and Infectious Diseases Hospital and a few of the more permanent murram pits or pools in other streams. But as soon as the early rains of February or March provide further areas of stagnant water it begins to spread until during June it occupies in great force almost every available pool, pit, and puddle in and around the township.
>
> Nairobi communities are losing in cash every year, nearly £4,000 through malaria. They are losing, in addition, from the same cause, some 35 to 40 people whose "cash" value cannot be ascertained, and another unknown amount through impairment of health and efficiency that so often results from malaria. Can we assume that these last two losses amount to at least another £4,000?
>
> Specific efforts to prevent these losses over some ten years have cost about £1,000 a year. It is now obvious that such efforts are inadequate.
>
> In order to put an end to this annual loss of £8,000, what ought the community to be prepared to expend on permanent control measures?

Workers contemplating gambiae control in Africa should not be too greatly influenced by the amount of money spent on gambiae eradication in Brazil. It should be remembered that the Malaria Service of the Northeast worked under emergency conditions, spent large sums on the treatment of malaria, and purchased much equipment and material which was never used. Also the Service never succeeded in making careful studies to determine how long control measures must be continued after the species can no longer be found in a community. It is known that the three

months' period adopted errs in being too conservative. The results in certain areas suggest that an intensive campaign of combined antilarval and anti-imaginal measures of six weeks will be sufficient to clean many places completely. The cost of gambiae eradication in future campaigns can definitely be greatly reduced far below that of the work in Northeast Brazil.

As time goes on it will almost certainly be found that an increasing number of areas can be cleaned of gambiae and freed of gambiae-transmitted malaria. The problem of eradication in Africa would, of course, be centrifugal rather than centripetal; in Brazil the thwarting of rapid expansion required the cleaning of the periphery first, together with protection of the frontier zones, but in Africa, where the species is already widely disseminated, it would seem logical to attempt eradication by beginning at the center of the area to be cleaned and working always outward. While it is true that cleaned areas in Africa will not enjoy the barrier of hundreds of miles of ocean against reinfestation of clean areas, there is no question in the minds of those who have worked on the problem in Brazil but that once a fairly large area has been cleaned, the maintenance cost of frontier services to prevent the reinfestation of those clean areas, and the elmination of such reinfestations as may occur before they become important problems, will be far less than any other possible means of controlling malaria in that area. It remains to be seen whether *A. funestus,* another very efficient vector of malaria in Africa, will respond equally well to the same technique. This point is important since *A. gambiae* and *A. funestus* are active collaborators in many areas of Africa.

FEASIBILITY OF GENERAL SPECIES ERADICATION MEASURES

It has been demonstrated in Brazil that species eradication of *Aedes aegypti* and *Anopheles gambiae* is feasible. The question naturally arises as to whether practical species eradication methods can be worked out for other disease transmitters, other mosquitoes and insects. This will depend somewhat on the financial limits to be put on the term "practical." It will be argued by many that

species eradication is an expensive luxury and that funds for this type of work could never be gotten in the districts in which they work. However, if species eradication is even remotely possible with available methods against a given species in a given region, it is well to consider the amount of money spent annually in partial control work and the loss attributed to the disease under consideration over a period of some decades, before deciding against species eradication on the basis of cost.

Before deciding on species eradication, the following points should be established:

that the insect to be eradicated produces enough disease in the community to justify the expenditure of the necessary funds;

that the insect is susceptible to attack in one or more, preferably all stages of its life cycle;

that it is possible to eradicate the species from small areas;

that the area in which eradication is to be attempted possesses natural barriers against constant reinfestation or is large enough to make the cost of maintenance of a permanent clean frontier zone, an item of minor expense for the entire clean area;

that the necessary money, men, and authority to carry out the program will be available when needed;

that the insect in question can be easily found in at least one of the stages of its life cycle so that negative findings can be interpreted as definite indication of its absence from areas surveyed.

Before taking these preliminary requirements too seriously, it should be noted that many of them were not fulfilled before the development of the campaigns against *Aedes aegypti* and *Anopheles gambiae* in Brazil, and against the Mediterranean fruit fly in Florida. The Yellow Fever Service developed its technique for the eradication of aegypti in the course of a mosquito reduction program, and the Malaria Service of the Northeast undertook the eradication of gambiae under emergency conditions with a large infested area from which dissemination of the species was proceeding apace. Each additional extension of its range further compli-

cated the problem of control, not only because of the increased area in which control measures had to be applied, but also by creating serious outbreaks of malaria which had to be taken care of by personnel sorely needed in the organization of antigambiae measures. Under these conditions it was not feasible to lose time in making careful surveys or extensive preliminary studies of possible control methods; it seemed rather more expedient to learn how to get rid of gambiae by actually getting rid of gambiae.[1]

The campaign against gambiae differed from previous campaigns against malaria in that the objective was not simply the control of malaria in the local population, but the eradication of the vector in the entire area, not only to protect the local population against malaria, but also to prevent its spread to other regions. When the declared purpose of a campaign is the eradication of a species rather than the reduction in the incidence of disease caused by that species, the entire viewpoint of the service changes almost automatically. As long as evidence for the existence of the species continues to appear, the campaign has been a failure; there is no such thing as partial success in species eradication, one either achieves glorious success or dismal failure. Estimates of progress based on the traditional method of the malariologist, such as spleen rates, blood parasite rates, clinical attack rates, infant infection rates, become invalid and subordinated to the simple question, "Is the species under attack still present in the area being worked?"

This point of view is in direct disharmony with that of the modern malariologist, as is revealed by a perusal of the words of

[1] Ross (1910) called attention to the "learning by doing" technique as applied to the control of malaria:

Amateurs are fond of advising that all practical measures should be postponed pending carrying out detailed researches upon the habits of anophelines, the parasite rate of localities, the effect of minor works, and so on. In my opinion, this is a fundamental mistake. It implies the sacrifice of life and health on a large scale while researches which may have little real value and which may be continued indefinitely are being attempted. As a matter of fact, the campaigns of Havana, Panama, Ismailia, and the Federated Malay States were all commenced before the local carriers were definitely incriminated and their habits studied. . . . In practical life we observe that the best practical discoveries are obtained during the execution of practical work and that long academical discussions are apt to lead to nothing but academical profit. Action and investigation together do more than either of these alone.

the Special Committee on Malaria, of the League of Nations (Hackett, *et al.*, 1938):

> As for the reluctance and criticism arising from a fear of incomplete success, we would like again to stress the point that in dealing with rural malaria, speed and perfection are costly out of all proportion to their worth. We believe in taking a *long-time view*[1] of the malaria problem and in having patience to prefer steady progress, slow and imperfect though it may be, to an indefinite postponement of any work whatever.

This may be good philosophy for the defeated, but results of work with both *Aedes aegypti* and *Anopheles gambiae* indicate that it is much easier to evaluate perfect rather than partial results. If the time and money spent on evaluating partial results were spent on obtaining perfect results, greater progress might be made over a given period. It is when one takes the long-time view of the malaria problem that justification for attempting species eradication is found. By the creation of very large malaria control areas and pooling all resources for malaria work in both towns and rural districts, it should be possible in many areas to eradicate the responsible local vector at a great saving over a period of years. To quote once more: "The Committee desires to stress the fact that rural malaria, especially in the tropics, is one of the principal unsolved problems in the field of Public Health. . . ."

Those who have had an active part in the eradication of gambiae from Brazil hope that the work of the Malaria Service of the Northeast has done more than solve the local rural problem and that results of the attack on gambiae in Brazil may lead to the development of methods which will help solve for many rural areas, within and outside the tropics, their especial individual, malaria problems.

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[1] Italics not in original.

SUMMARY

The arrival of *Anopheles gambiae* in Brazil in 1930 was followed by serious outbreaks of malaria in 1930 and 1931. The first organized campaign in 1931 apparently resulted in the eradication of gambiae from Natal, its port of entry, but not until after it had found a footing in the relatively inhospitable interior of Rio Grande do Norte. From 1932 to 1937 it was more or less quiescent until it encountered more favorable conditions in the Assú and Apodí valleys of Rio Grande do Norte, and the larger and more favorable valley of the Jaguaribe, in Ceará. In 1938, terrific outbreaks of malaria with a high fatality rate occurred in the two states. To meet this emergency, the government organized the Antimalaria Service which was fused in January 1939 with the Malaria Service of the Northeast, a cooperative service organized solely for the purpose of combating the gambiae mosquito and supported by the Ministry of Health of Brazil and the International Health Division of The Rockefeller Foundation. The Malaria Service of the Northeast, with the aid of the already existing Yellow Fever Service, undertook to organize a campaign of species eradication against gambiae, relegating the problem of malaria itself to a place of minor importance. After several disappointing months of intensive organization, the Malaria Service began a heavy attack with Paris green and pyrethrum spray insecticide on gambiae in both larval and adult forms, and initially concentrated its efforts on the peripheral and frontier zones. Gambiae was stopped in its career of invasion, was beaten back, and finally eradicated from the known infested area in less than two years' time. Observations covering a period of a year and a half, including two rainy seasons, after the suspension of all antigambiae measures, indicate that eradication has been complete. Precautions must be taken to prevent reinfestation by gambiae and the introduction of other vectors or diseases by modern facilities of rapid transportation.

APPENDIX I

LEGAL DECREE NO. 1,042

The President of the Republic, by reason of the powers conferred upon him by Article 180 of the Constitution, DECREES:

Article 1. The Malaria Service of the Northeast is hereby created in the Ministry of Education and Health.

Article 2. The Malaria Service of the Northeast shall be responsible for:

a. promoting the study and investigation of the transmission of malaria by the mosquito *Anopheles gambiae,* in the northeast of Brazil;

b. applying all measures necessary to fight the mosquito *Anopheles gambiae* in the northeast, as well as to prevent its spreading to other parts of the national territory;

c. applying all complementary measures relative to the fight against malaria in the northeast, such as treatment of the sick, and health education of the population, etc.

Article 3. The Malaria Service of the Northeast shall be headed by a specially appointed director with a Class O salary.

Paragraph 1. The technical and administrative personnel of the Malaria Service of the Northeast shall be appointed in accordance with provisions of the law.

Article 4. The Federal Government is empowered to entrust the direction and administration of the Malaria Service of the Northeast to The Rockefeller Foundation for the period of time deemed necessary.

Paragraph 1. The financial contribution of The Rockefeller Foundation as well as the administrative regulations under which the Malaria Service of the Northeast will operate according to the provisions of this article, will be specified in the contract to be signed with the Foundation by the Ministry of Education and Health.

Article 5. The necessary expenditures for the operation of the Malaria Service of the Northeast, in 1939, shall be charged to the funds of the special budget as established by Legal Decree No. 1,007, of December 30, 1938.

Article 6. This law shall be in effect as from the date of its publication.

Article 7. Provisions to the contrary are hereby revoked.

Rio de Janeiro, January 11, 1939, 118th of the Independence and 51st of the Republic.

[Signed] Getulio Vargas
Gustavo Capenema

APPENDIX II

TERMS OF CONTRACT DRAWN UP BY THE MINISTRY OF EDUCATION AND HEALTH AND THE INTERNATIONAL HEALTH DIVISION OF THE ROCKEFELLER FOUNDATION FOR THE STUDY AND COMBAT OF ANOPHELES GAMBIAE THROUGHOUT BRAZIL DURING THE YEAR 1939.

On the twenty-sixth day of January, 1939, there being present in the Department of Financial Affairs of the Ministry of Education and Health, the respective Minister, Dr. Gustavo Capanema, representing the Federal Government, and Dr. Fred L. Soper, duly authorized representative of the International Health Division of The Rockefeller Foundation, the latter stated that the said Division would assume responsibility for the studies of and campaign against *Anopheles gambiae* during 1939 throughout Brazil, under the following conditions:

First—The International Health Division of The Rockefeller Foundation will assume entire responsibility for the combat and study of *Anopheles gambiae* throughout the entire northeastern part of the country, from the first day of January to the thirty-first day of December, 1939. Should the existence of *Anopheles gambiae* be verified in other parts of the national territory, the International Health Division of The Rockefeller Foundation will extend its activities to those localities.

Second—The representative of the International Health Division of The Rockefeller Foundation shall be the director of the Malaria Service of the Northeast, and shall have the power to choose employees and stipulate the conditions under which they work with the approval of the Ministry of Education and Health.

Third—In selecting candidates for the technical staff, preference will be given to those who present proof of having satisfactorily completed a course of training in malariology or of having had long experience in antimosquito work.

Fourth—The two parties to this contract shall designate, in accord with available information as to the results of entomological surveys, the areas in which antilarval measures against *Anopheles gambiae* are to be carried out.

Fifth—In addition to the campaign against *Anopheles gambiae,* complementary measures for the control of malaria, such as treatment, chemical and mechanical prophylaxis, education of the public, etc., will be undertaken at the discretion of the Director of the Malaria Service of the Northeast.

Sixth—Since the International Health Division of The Rockefeller Foundation is cooperating with the Federal Government, it is understood that the legal entity, for all purposes, shall be the Malaria Service of the Northeast, of the Ministry of Education and Health.

Seventh—In combating and studying *Anopheles gambiae,* the personnel of the Malaria Service of the Northeast shall have authority to enforce such

health measures as now exist or may later become effective, relating to the collection of blood samples, control of mosquitoes, notification of deaths, permits for burials, examination of bodies, the performing of autopsies or any other measures which may be of interest to the Malaria Service of the Northeast.

Eighth—When on duty the doctors and authorized employees of the Malaria Service of the Northeast shall be entitled to exemption from postal and telegraphic charges, to passes on government railroads and to discounts allowed public departments by ocean and river navigation and air transportation companies, all such concessions being extensible to employees in charge of posts where the Service does not maintain resident doctors. Authorized doctors and other employees shall requisition passes for subordinates and for transportation of necessary materials on government railroads as well as free telegraphic service on government lines.

I—Passes, transportation, and telegrams requisitioned from government lines shall be considered to be in the public interest and, therefore, not chargeable.

II—Expenses incurred through the requisition of passes, transportation, and telegrams on government lines shall be considered as part of the contribution of the Federal Government to the Malaria Service of the Northeast, in charge of The Rockefeller Foundation.

Ninth—The personnel and material of the Antimalaria Service of the Ministry of Education and Health, now operating in the Northeast, shall be incorporated in the Malaria Service of the Northeast.

Tenth—The Malaria Service of the Northeast may, whenever necessary, request the collaboration of other federal, state, and municipal departments directly or through their respective ministers, interventors, or mayors, in applying the necessary technical measures or in securing necessary supplies.

Eleventh—For the execution of the service herein contracted, the Federal Government will contribute 5,000 contos ($250,000 U.S.) and the International Health Division of The Rockefeller Foundation the sum of $100,000 (one hundred thousand dollars), including in this figure the value of material supplied by the Division.

For the execution of this clause, the following conditions are established:

I—The quota of the Foundation ($100,000) in milreis shall depend on the exchange rates in force at the time payments are being made by the Division;

II—The Federal Government shall deposit in advance, in the Bank of Brazil, its corresponding quota (5,000 contos) to the credit of the representative of the International Health Division of The Rockefeller Foundation in Brazil, after due registration of this contract, the interest accruing to revert in favor of the National Treasury;

III—The cost of the Malaria Service of the Northeast shall be debited to the contributions of the Federal Government and the International Health

Division of The Rockefeller Foundation in the proportion of 70% (seventy per cent) to the former and 30% (thirty per cent) to the latter;

IV—Should the contribution of the Division become exhausted, due to modifications of the exchange rate, further expense shall be met exclusively by the quota of the Federal Government;

V—Financial statements of the total expenditures of the Malaria Service of the Northeast shall be submitted by the International Health Division of The Rockefeller Foundation showing that the stipulations of Item III are being carried out.

VI—The taxes and imposts already created or which may be created by law during the term of this contract, which financially affect the budget of the Malaria Service of the Northeast, shall be charged against the sum of 5,000 contos ($250,000 U.S.) herein established as the quota of the Government.

Twelfth—The salaries and traveling expenses of the doctors of the staff of the International Health Division of The Rockefeller Foundation, who may be brought to Brazil for work with the Malaria Service of the Northeast, shall be paid by the Division and, therefore, shall not be subject to the terms and conditions of the eleventh clause of the present contract and its subitems.

Thirteenth—The expenses up to 5,000 contos ($250,000 U.S.) entailed in carrying out the present contract which will be valid until December 31, 1939, shall be chargeable to the reserve set up by the special credit opened by Legal Decree No. 1,007 of December 30, 1938.

Fourteenth—Reports on the work of the Malaria Service of the Northeast shall be sent monthly to the Ministry of Education and Health and to the Director of the National Health Department, in addition to any other information which may be requested from time to time.

Fifteenth—Personnel, equipment, and transportation facilities of the Malaria Service of the Northeast and of the Yellow Fever Service shall be interchangeable.

Sixteenth—The present contract shall only become effective after due legal registration, the Government not being liable for any indemnity should registration be refused.

Seventeenth—Under the terms of Art. 36, No. 72 of Decree No. 1,137 of October 7, 1936, the present contract is exempt from the stamp tax. And since both parties are in agreement, the present contract has been drawn up, which on being read and found in order, will be signed by Dr. Gustavo Capanema, Minister of Education and Health, on behalf of the Federal Government, and by Dr. Fred L. Soper, representative of the International Health Division of The Rockefeller Foundation, by the witnesses below and by me, José Medeiros de Carvalho, administrative officer of class "J," who drew up this contract.

Rio de Janeiro, January 26, 1939—[signed] Gustavo Capanema, Fred L. Soper, and the witnesses: J. A. Kerr, José Medeiros de Carvalho, and Jorge Modesto de Almeida.

APPENDIX III

DECREE No. 21,434 OF MAY 23, 1932, APPROVING THE REGULATIONS OF THE SERVICE FOR THE PREVENTION OF YELLOW FEVER IN BRAZIL

Article 1. Personnel of the Yellow Fever Service shall visit weekly, unless in the judgment of the Service there should be reasons justifying a shorter or longer inspection cycle, all premises, inhabited or otherwise; private and collective dwellings, including kitchen gardens, outhouses, open sheds, etc.; factories, shops, commercial and industrial establishments, colleges, retreats, convents, churches, monasteries, cemeteries, hospitals, markets, hotels, restaurants, boardinghouses, stables, barns, barracks, prisons, forts, islands, dry docks, ship docks, stores of every kind including explosives or inflammable materials, military and civil aerodromes, all means of transport, whether by land, sea, river, or air; lots, parks, and public places; gardens and all similar places.

Section 1. The above-mentioned premises shall be minutely inspected in all their various parts, outside and inside, including rooms and sleeping quarters.

Article 2. Physicians of the Service and their representatives shall have immediate free entry at all times to all places mentioned in the previous article in order to make the prescribed inspections.

Article 3. Said inspections shall be made for the following purposes:

a. to prevent the breeding of mosquitoes;

b. to discover and destroy in accordance with the measures prescribed by these regulations the actual and potential breeding places of mosquitoes;

c. to indicate methods for the correction of the irregularities detected which have a bearing upon the prevention of yellow fever;

d. to collect any information of interest to the Service.

Section 1. Physicians of the Service and their representatives shall advise, summon, and, by legal procedure, compel those concerned to remedy the defects encountered during inspections.

Article 4. Anyone who in any way opposes, hinders, or raises obstacles to the public health work defined in these regulations shall be liable to a fine of from 100$000 to 1:000$000 ($5 to $50 U.S.) this to be doubled in the event of a subsequent offence, or imprisonment of from three to thirty days.

Section 1. The penalty laid down in this article may, at the sole discretion of the Service physician, be held in abeyance for a period of forty-eight hours in order to allow the offender an opportunity of adducing justification. If, on the expiry of the period of grace this has not been produced, or if it is found inacceptable to the Service, the penalty will be duly notified and enforced.

Section 2. When persuasive and coercive methods have been exhausted, recourse shall be had to the police authorities for the enforcement of the Service regulations.

Section 3. In cases of insolence or abuse, in addition to the penalty threatened in the present article, proceedings shall be taken in competent courts.

Article 5. Unoccupied premises which cannot be visited because the address of the person holding the keys is unknown, or because he delays in producing or refuses to produce said keys, or makes other difficulties, shall be placed under seal until facilities for inspection are afforded.

Section 1. In such cases, the Service shall proceed to open the premises, in the presence of police authorities, in order to make the inspection, after which they shall be reclosed and sealed.

Article 6. No occupation permit shall be furnished unless all the provisions of these regulations have first been fully satisfied.

Article 7. The occupant of the premises on which mosquito breeding places have been found, either in the interior of said premises or in outhouses or the like, shall be liable to a fine of from 5$000 to 50$000 ($0.25 to $2.50 U.S.), this to be doubled in the event of a subsequent offence.

Section 1. All places and localities referred to in Article 1 of these regulations shall come within the ambit of the above article.

Article 8. Whenever a Service employee finds a mosquito breeding place, he shall destroy the receptacle in which it was found, or, alternatively, apply the larvicide used by the Service.

Section 1. Water containers (potential breeding places) which are not sufficiently mosquito proofed shall be dealt with in conformity with the above article, because the indications given under Article 3 of these regulations have not been obeyed.

Article 9. Procedures of formal summons and prosecution shall be organized in conformity with the existing rules of the National Department of Public Health.

Section 1. The summons must be signed by one of the Service physicians.

Section 2. The charge must be signed by the inspecting employee who detected the irregularity.

Section 3. The fine may be imposed only by one of the Service physicians.

Article 10. The mosquito-proof closing of all water containers, of every description, is obligatory.

Section 1. This must be done by the persons in charge of said containers.

Section 2. The overflow outlets of all water containers must be protected against mosquitoes.

Section 3. The utmost vigilance shall be exercised by the occupants of all premises, especially in regard to taps, water piping, rainwater spouts, etc., so as to avoid leaks and stagnation of water.

Section 4. Infringement of this article shall be punishable by a fine of from 5$000 to 50$000 ($0.25 to $2.50 U.S.), this to be doubled in the event of a subsequent offence.

Article 11. Whenever a domestic water tank is opened for inspection, cleaning, or repair, the party responsible shall immediately close it again in such a way as to make it mosquito proof, on penalty of a fine of from 10$000 to 100$000 ($0.50 to $5 U.S.), this to be doubled in the event of a subsequent offence.

Article 12. Water containers shall always be situated in places easily accessible to the inspectors; wall tanks to be located not less than fifteen centimeters from the walls and sixty centimeters from the ceiling or roof.

Section 1. It is prohibited to keep objects on the lids of water tanks.

Section 2. Proprietors are obliged to supply a means, such as a ladder or the like, to facilitate the inspection of wall tanks that are considered not easily accessible by the Service.

Article 13. Automatic flushing-tanks shall be so placed as to permit inspection of the interior.

Section 1. These tanks shall be maintained in perfect working order.

Article 14. Where there is a constant supply of water, domestic tanks shall not be permitted.

Article 15. In areas where there is an adequate water supply, the storage of water in barrels, tubs, tins, and similar vessels is prohibited under penalty of the immediate destruction of these receptacles.

Section 1. Otherwise the following exceptions may be allowed at the discretion of the Service:

Barrels, large earthenware vessels, and other similar water containers, all of which must conform to the models approved by the Service, will be tolerated, provided, however, that they shall either be mosquito proofed or kept constantly stocked with larvivorous fish of a species approved by the Service.

Section 2. Artificial lakes and also basins which usually contain water shall be stocked with larvivorous fish of a species approved by the Service.

Section 3. The duty of providing and maintaining the stock of fish mentioned in the article shall rest with the occupant.

Article 16. Only basements which may easily be inspected and will absolutely not collect water shall be allowed.

Section 1. Should it be found quite impossible to satisfy the requirements of this article in respect of inspection facilities, the proprietor shall be compelled, at the discretion of the Service physician, to install suitable trap doors in the flooring, the specifications of which, as regards the number and location, shall be determined by the Service physician himself.

Section 2. Basements shall not be used as hen houses or as accommodation for animals of any kind.

Article 17. Drains and sewer-traps shall not be allowed in places where they would be difficult to inspect.

Article 18. The pavement of open areas and walks shall be level, without any depression, and have a sufficient incline for the water to drain away readily.

Article 19. Channels shall be so maintained that the water cannot be retained at any point along their courses.

Article 20. Ornamental work, façades, eaves, stone carving, roofs, and awnings of buildings shall be constructed in such a manner that they cannot collect water.

Article 21. Topping of walls with broken glass or broken bottles is prohibited.

Article 22. Existing edifices, as well as those constructed thereafter, shall have only such roof gutters as are absolutely indispensable.

Section 1. Such roof gutters must have a sufficient capacity and slant to ensure that rain water will never be retained at any point. In addition, they shall be provided, at distances of not less than six meters, with discharge pipes made of material which is not easily crushed.

Section 2. Furthermore, roof gutters or rain water discharge pipes may not be used to drain off any other water, including the overflow from wall tanks.

Article 23. Wherever there are roof gutters, the proprietor in charge shall arrange that the roofs are easily accessible for the inspection of said gutters.

Article 24. Metal roofs shall not be constructed of sheet metal that can be easily bent and may therefore collect water in the depressions thus formed.

Article 25. Acting upon the findings of roof-gutter inspections, the Service physician shall summon or take legal action against the responsible party so as to obtain the prompt correction of the defects observed.

Section 1. In case of noncompliance with the summons, the roof gutters found to be defective shall either be removed or perforated by the personnel of the Service itself according to the Service physician's ruling.

Article 26. Storm sewers shall be kept clean by the responsible parties, each of whom shall ensure the cleansing of the particular section of the system for which he is answerable.

Article 27. Storm sewers, as well as manholes of electrical underground power lines, telephone cables, and the like, and also the places used for inspection purposes by the city water and fire departments, shall be so arranged that they cannot collect water and shall be closed in such a manner as to be mosquito proof.

Article 28. Drinking water receptacles for animals in the public livery stables, stable studs, poultry yards, etc., shall be so designed that they can be quickly and completely emptied.

Section 1. To that end the said drinking receptacles should be designed in the form of a truncated cone.

Section 2. Infringements of this article shall be punishable by a fine of from 50$000 to 500$000 ($2.50 to $25 U.S.), this to be doubled in the event of a subsequent offence.

Article 29. Flower vases, jars, jardinières, and other ornamental articles in cemeteries, shall never be allowed to contain water.

Section 1. All these receptacles shall be permanently filled with sand.

Section 2. Mausoleums, vaults, and burial urns shall be maintained in such condition as not to collect water.

Section 3. Cemetery administrators shall be responsible for ensuring that water does not collect in excavations and tombs.

Article 30. In the construction of buildings, and in any work involving excavation, no stagnant water shall be allowed to remain.

Section 1. In foundations or cellars where water accumulates through infiltration or rain, the party responsible shall be obliged to apply oil weekly at his own expense.

Section 2. Infringements of this article shall be punishable by a fine of from 100$000 to 1:000$000 ($5 to $50 U.S.), this to be doubled in the event of a subsequent offence.

Article 31. Wells, in areas where permitted, must be closed in such a way as to be mosquito proof and provided with pumps or, if of the open type, kept permanently stocked with larvivorous fish of the species indicated by the Service.

Section 1. Furthermore, whenever possible, the well shall be completely and permanently filled in by the responsible party.

Section 2. The adoption of one or other of the above expedients shall rest with the Service physician.

Section 3. Infringements of this article shall be punishable by a fine of from 50$000 to 500$000 ($2.50 to $25 U.S.), this to be doubled in the event of a subsequent offence.

Article 32. Spring water shall be caught and run off through pipes by the owner or tenant so as to prevent the breeding of mosquitoes.

Section 1. Infringements of this article shall be punishable by a fine of from 100$000 to 1:000$000 ($5 to $50 U.S.), this to be doubled in the event of a subsequent offence.

Article 33. In public and private gardens and parks, control cocks for watering purposes shall be so arranged as to prevent the collection of water.

Article 34. In order that without inconvenience they may be treated with larvicides drains must never discharge into artificial ponds.

Article 35. Plants which, by the arrangement of their foliage, are able to collect water and thus serve as places for the breeding of mosquitoes shall, at the discretion of the Service, be destroyed.

Article 36. The use of unsplit bamboo for the construction of enclosures or as stakes is prohibited.

Article 37. The use of bamboo poles shall be permitted only when they are so treated that the ends cannot collect water.

Article 38. Cavities in trees must be filled with concrete.

Section 1. This must be done by the owner of the property or his tenant.

Article 39. Devices of a type able to hold water for protecting plants, beehives, etc., from ants shall not be permitted and shall accordingly be destroyed.

Article 40. All kitchen gardens, orchards, vacant lots, and commons inside of the limits determined by the Service shall be kept cut and free from tin cans, pans, and other like receptacles which can collect water.

Article 41. Any person who at any time litters the ground with tin cans, pans, dishes, glassware, pottery, and other articles capable of collecting water shall be punished by a fine of from 5$000 to 50$000 ($.25 to $2.50 U.S.), this to be doubled in the event of a subsequent offence.

Article 42. Owners of land or gardens containing natural pools or marshy tracts shall be required to drain them or, as an alternative, fill them in, under penalty of a fine of from 100$000 to 1:000$000 ($5 to $50 U.S.), this to be doubled in the event of a subsequent offence.

Article 43. Ditches, small streams, and gullets shall be kept clean and unobstructed by the responsible parties so that there is always sufficient current of water to make the breeding of mosquitoes impossible.

Section 1. Banks and beds shall be rectified, freed from weeds, and when the Service physician judges necessary, equipped with protective and supporting structures.

Section 2. Infringements of this article shall be punishable by a fine of from 50$000 to 500$000 ($2.50 to $25 U.S.), this to be doubled in the event of a subsequent offence.

Article 44. Animals running loose on public highways or open fields where there are ditches shall be rounded up, the Service calling upon the responsible municipal department for assistance in the matter.

Section 1. If any damage is sustained, the owners of the animals concerned shall be liable to the penalities described in this article.

Section 2. The guilty parties shall be fined from 20$000 to 100$000 ($1 to $5 U.S.), this to be doubled in the event of a subsequent offence.

Article 45. Ironware in industrial yards, storage depots, stockyards, and the like shall be kept in such condition as to preclude the collection of water.

Section 1. Infringements of this article shall be punishable by a fine of from 200$000 to 2:000$000 ($10 to $100 U.S.), this to be doubled in the event of a subsequent offence.

Article 46. In zones not having a sewerage system, the cesspools shall be kept in mosquito-proof condition.

Article 47. The cleaning of all sewer mains and catch basins, in order to avoid stagnation or overflow, is obligatory.

Article 48. Where the Service deems necessary, there shall be affixed a notice indicating the dates of inspectors' visits, the party responsible being required to preserve this document.

Article 49. Water containers on all boats shall be kept mosquito proof by the means approved by the Service.

Section 1. The parties responsible for the use of containers which are not kept in the above-mentioned condition shall be punished by a fine of from 50$000 to 500$000 ($2.50 to $25 U.S.), this to be doubled in the event of a subsequent offence.

Article 50. The use of old automobile tires as fenders on the sides of watercraft shall only be permitted when the holes made in them are not less than an inch and a half in diameter and not more than twenty centimeters apart, so that they cannot retain water.

Article 51. The immediate notification to the Service of all definitely ascertained or suspected cases of yellow fever is compulsory.

Article 52. The practice of viscerotomy and the practice of making systematic autopsies of all cases of interest to the Service shall be established.

Section 1. The Service may appoint local representatives, duly trained in the practice of viscerotomy and to whom deaths which occur within less than eleven days of the onset of sickness must be compulsorily notified without delay.

Section 2. In places in which the Service has a representative for the performing of viscerotomy, the certificates passed by the *Official do Registro Civil* giving permission for burial in cemeteries, chapels, churches, or private grounds shall only be issued on production of a death certificate bearing the visa of the said representative.

Article 53. Opposition to these measures shall entail a fine of from 50$000 to 1:000$000 ($2.50 to $50 U.S.), and immediate action by the police authorities who shall order immediate and compulsory autopsy or viscerotomy.

Article 54. Duty of notification shall devolve upon the following persons:

a. The attending or consulting physician; or, failing him, the head of the family or nearest relation who lived with the patient or suspect, or his nurse, or companion;

b. In apartment houses, the manager or person in charge, even though the notification has already been made by the physician or other person;

c. Persons in charge of commercial or agricultural concerns, colleges, schools, asylums, sanatoria, general hospitals, day nurseries, foundling or maternity hospitals, dispensaries, clinics, or like establishments in which the patient or suspect finds himself.

Article 55. For the purpose of these regulations, the term "Service" is understood to mean the Yellow Fever Service of the National Department of Public Health of Brazil.

Article 56. The term "responsible party" used in these regulations refers to the person as determined by the Service upon whom the duty of applying the prescribed measures devolves.

Article 57. By "viscerotomy" is understood the making of an incision in the cadaver with a view to taking specimens of any organ for the purpose of checking diagnosis.

Article 58. The Service may utilize any rule or law of the Regulations of the National Department of Public Health which is in force and is applicable to the yellow fever work.

Article 59. Infringements of articles of these regulations to which specific penalties are not attached shall be punishable by a fine of from 20$000 to 200$000 ($1 to $10 U.S.), this to be doubled in the event of a subsequent offence.

Article 60. All the provisions of these regulations, as well as the penalties laid down, shall be applied wherever necessary for the operation of the Service throughout the national territory.

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